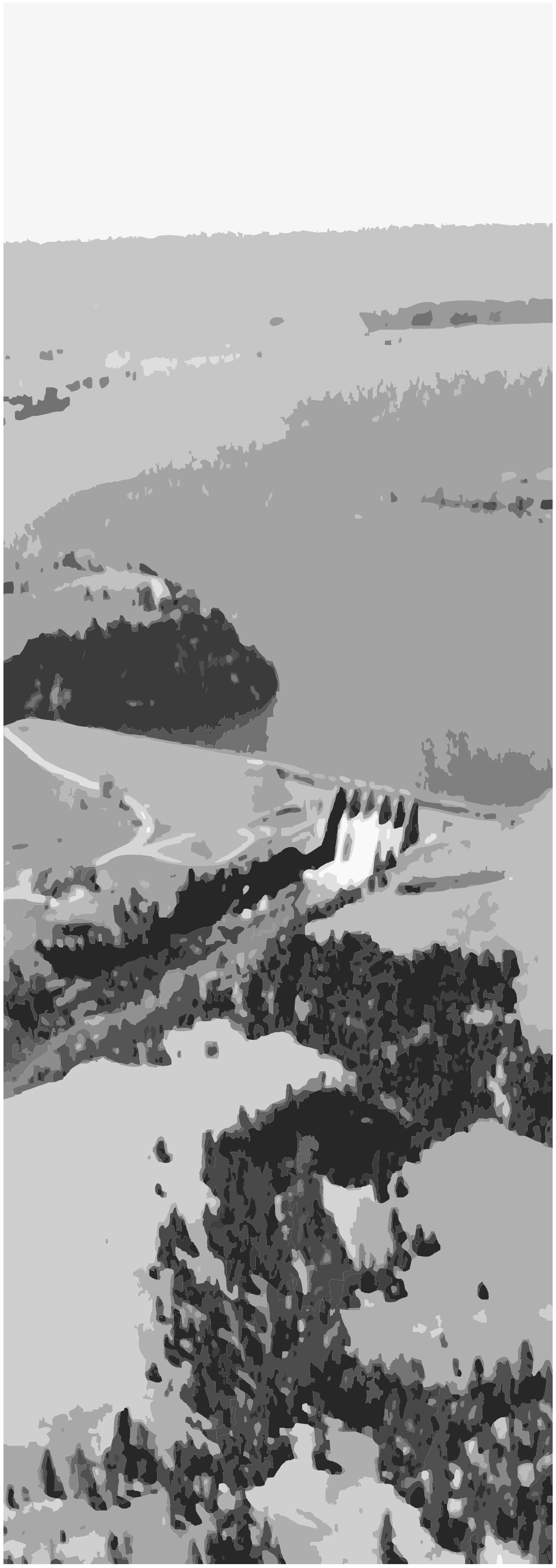


CHAPTER THREE
Affected Environment

This chapter describes environmental factors of the Angostura Reservoir area that could be affected by the alternatives detailed in Chapter Two. These factors are:

- Surface Water Quantity
- Surface Water Quality
- Groundwater
- Sediment
- Stream Corridor
- Wetlands
- Fisheries
- Wildlife
- Threatened or Endangered Fish and Wildlife Species (including State Species of Special Concern
- Social and Economic Conditions
- Indian Trust Assets
- Environmental Justice
- Cultural Resources
- Paleontological Resources.

Impacts are analyzed in Chapter Four and summarized in Table S.1 in the Summary.

To make it more understandable, some of the technical information in Chapters Three and Four has been summarized from appendix data (see Contents for a list of appendixes). Readers wanting more information should consult the appendixes on the CD in the back of this EIS (environmental impact statement) (printed copies are also available on request.)

SURFACE WATER QUANTITY

Water available for future use was a concern of the public, and analyses of other environmental factors depended on the findings of this section. Measurements chosen to indicate changes (called *indicators*) were EOM (end-of-month) reservoir contents and elevations, releases from the reservoir to the District (Angostura Irrigation District), releases to the river, and accretion and return flows.

The Cheyenne River, fed by runoff from rainstorms and the melting of snow in the spring, provides most of the water flowing into Angostura Reservoir (or inflows). The reservoir is the only large dependable source of surface water in the area (a description of the river can be found in Chapter One, "Angostura Area").

For purposes of this EIS, effects were considered from the reservoir downstream to where the Belle Fourche River joins the Cheyenne River (figure 3.1). Belle Fourche flows are large enough to mask water-quantity effects beyond this confluence. Water available in the reservoir was predicted by the AGRAOP computer model, using inflows into Angostura (including an evaporation allowance) for 1953-1997 to project water available for 1998-2042. (AGRAOP is detailed in Appendix A.) The model projected reservoir storage, ranging from a minimum elevation of 3163 feet (top of the inactive pool and the level of the District's canal inlet) to the top of the conservation pool at elevation 3187.2 feet. The 1981 area-capacity relationship was applied to Reclamation's DISSED computer model to predict future sedimentation in the reservoir.

Cheyenne River

Information on flows was gathered from the USGS (U.S. Geological Survey) at two gauging stations on the Cheyenne River and three tributaries above Angostura Reservoir, and at eight gauging stations on the main stem of the river and its tributaries below Angostura Dam. (The USGS also operates gauges on Cheyenne River tributaries further downstream between the Pine Ridge and Cheyenne River Reservations, but these are not affected by the Angostura Unit.)

Gauging locations are shown on figure 3.1. Period of record for each gauge, drainage area, average annual and median (50% chance of occurring) flows, highest and lowest annual average flows, annual average runoff, and instantaneous peak flows (some outside the period of record) are recorded in Table 3.1. (Reclamation's HYDROMET [Hydrological Meteorologic database] estimated inflows/outflows; adjusted inflows for the reservoir are included in the table, and Appendix B contains net computed inflows by month.)

Diversions above Angostura Dam affect flows. Many stock and irrigation reservoirs above the Edgemont gauge store about 45,000 AF (acre-feet) of water (U.S. Geological Survey 1998.) Lander Ditch diverts water above the Hat Creek gauge to irrigate hayfields, and diversions upstream of the Horsehead Creek gauge irrigate about 640 acres in the vicinity. Flows are also diverted from the Cheyenne below the dam and on the tributaries of the river. Fall River flows have been regulated by Coldbrook Reservoir since 1952 and Cottonwood Springs Lake since 1969. Diversions also occur above the Beaver Creek gauge 25 miles below the dam (U.S. Geological Survey 1998). Stockade Reservoir regulates flow on French Creek 12 miles upstream of the gauge.

Reservoir Inflows

Inflows were calibrated using AGRAOP by comparing historic EOM contents corrected for July 1958, and adjusted for the October 1966, and September 1981, area-capacity tables. Estimated adjusted inflows for 1953-1997

Fig. 3.1

USGS GAUGING STATIONS

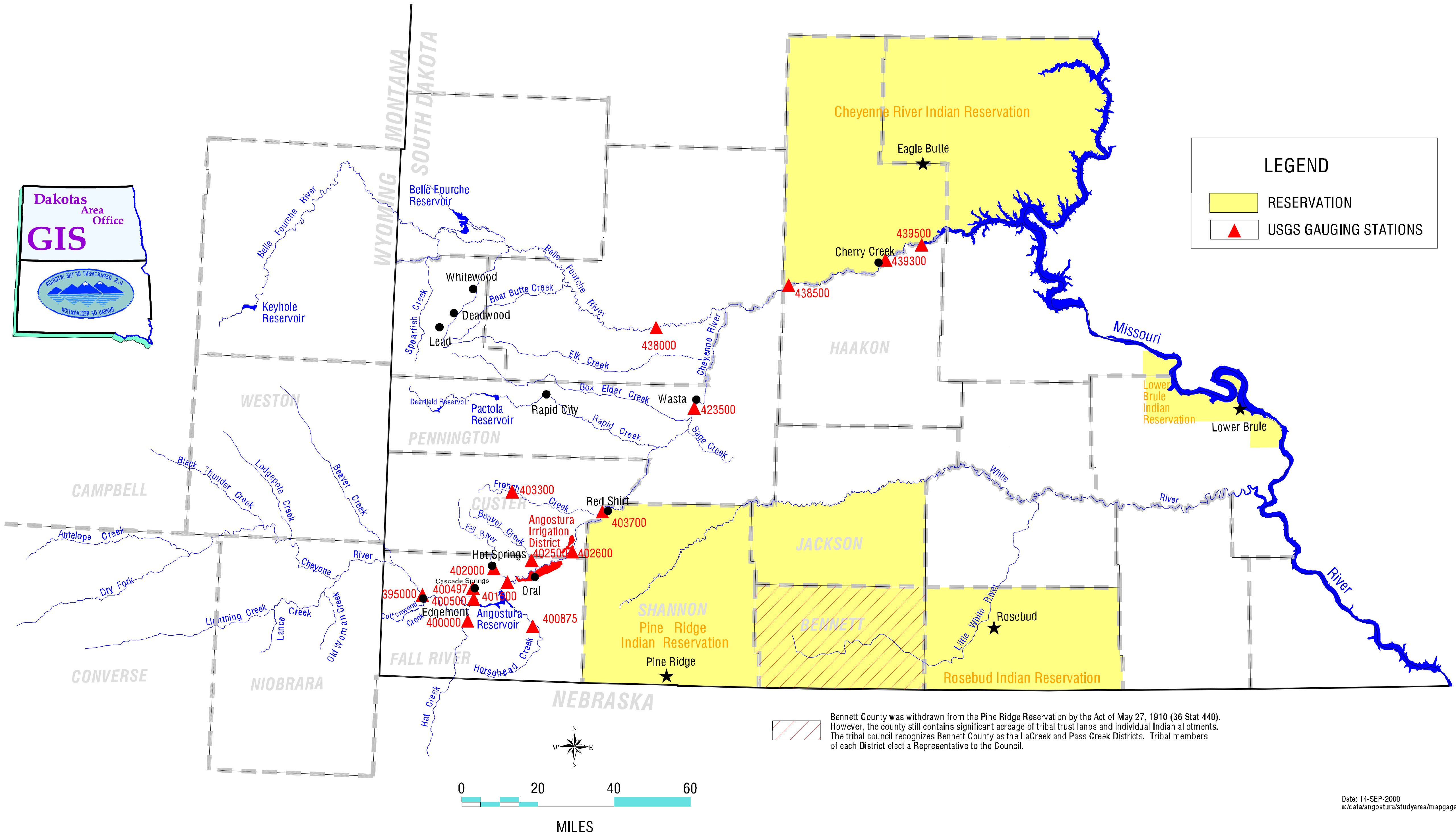


Table 3.1: Gauges Supplying Data for the EIS

Gauge	Station ID	Period of Record (Water Years)	Drainage Area (Square Miles)	Annual Average Flows (cfs [cubic feet/ second])	Median Flows (cfs)	Highest Annual Average Flows		Lowest Annual Averae Flows		Annual Average Runoff (Acre-feet)	Instan-taneous Peak Flows (cfs)
						(cfs)	(Year)	(cfs)	(yr.)		
Cheyenne River At Edgemont	06395000	1929-32 and 1947-97	7,143	81.4	10	434	1962	12.0	1988	58,990	28,000
Hat Creek Near Edgemont	06400000	1906 and 1951-97	1,044	16.9	0.4	112	1967	0.16	1989	12,230	13,300
Cascade Springs Near Hot Springs	06400497	1977 -95 Discontinued	0.47	19.5	19	21.4	1984	16.3	1993	14,150	49
Cheyenne River Near Hot Springs	06400500	1915-20 and 1943-72	8,710	139.9	—	453	1962	30.9	1961	101,400	114,000
Horsehead Creek at Oelrichs	06400875	1984-1997	187	7.21	0.0	29.3	1986	0.0	1990	5,220	8,270
Angostura Reservoir Adjusted Inflow	Adjusted	1951-97	9,100	123.6	—	565	1962	26.2	1961	89,500	N/A
Cheyenne River Below Angostura	HYDROMET Data	1953-97	9,100	59.9	—	404	1962	0.0	—	43,400	N/A
Cheyenne River Below Angostura	06401500	1951-78; partial year since 1978	9,100	67.1	1.4	404	1962	0.83	1961	48630	30,300
Fall River at Hot Springs	06402000	1970-97	137	21.9	22	25.5	1997	20.9	1981	15,880	13,100
Beaver Creek Near Buffalo Gap	06402500	1939-97	130	7.19	—	12.5	1995	3.78	1961	5,210	11,700
Cheyenne River Near Buffalo Gap	06402600	1969-80 Discontinued	9,800	107.4	—	263	1971	56.5	1976	77,900	25,000
French Creek Above Fairburn	06403300	1983-97	105	10.4	3.7	34.7	1995	1.01	1989	7,510	1,060
Cheyenne River at Red Shirt	06403700	1999	11,200	395	204	N/A	N/A	N/A	N/A	285,800	5,610
Belle Fourche River Near Elm Springs	06438000	1954-97	7,210	1,036	100	1,036	1996	28.4	1961	250,400	14,100
Cheyenne River Near Wasta	06423500	1964-97	12,800	340	123	1,143	1997	81.0	1989	246,200	26,900
Cheyenne River Near Plainview	06438500	1951-81 and 1995-97	21,640	722	260	2,417	1997	97.2	1961	522,900	69,700
Cheyenne River Near Cherry Creek	06439300	1961-94 Discontinued	23,900	802	261	1,748	1978	100	1961	581,000	55,900
Cheyenne River Near Eagle Butte	06439500	1934-67 Discontinued	24,500	924	N/A	N/A	N/A	N/A	N/A	668,900	104,000

Sources: USGS ***Water-Data Reports*** SD-72-1, SD-80-1, SD-94-1, SD-97-1;
HYDROMET Data

Table 3.2: Estimated Monthly Net Inflows, 1953-1997
(cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	31.7	83.1	195.8	125.0	326.4	360.7	157.6	83.9	34.3	26.1	29.3	27.4	123.5
Minimum	15.8	16.2	29.3	11.8	0.0	0.0	0.0	0.0	0.0	0.0	5.0	9.8	26.1
10-percentile	18.9	27.0	51.7	27.6	23.4	10.1	12.0	8.1	0.0	7.2	16.5	16.9	38.0
Median	26.2	45.0	128.5	87.4	102.5	127.7	55.3	39.0	18.5	22.8	26.9	26.0	92.1
90-percentile	44.0	151.3	417.3	270.9	1035.7	874.2	312.6	230.6	100.2	49.4	46.4	38.4	252.1
Maximum	145.4	696.8	800.2	847.0	2535.5	2831.7	1369.4	450.5	275.6	217.9	53.8	68.3	562.7

Source: HYDROMET database adjusted for evaporation and precipitation by the AGRAOP model.

averaged 89,500 AF (123.5 cubic feet/second, or cfs), with an annual maximum of 409,000 AF (562.7 cfs) in 1962, an annual minimum of 19,000 AF (26.1 cfs) in 1961. Annual median inflows were 66,900 AF/year (92.1 cfs), about 75% of the annual average. Table 3.2 shows the monthly/annual inflow statistics for the 45-year period of record, including average, minimum, maximum, and 10-, 50- (median), and 90-percentile frequency of occurrence (10 percentile, as an example, means 10% of recorded values are equal to or less than the values in the table). Appendix C contains adjusted inflows into the reservoir, including a graphic depiction.

Gauges upstream of the reservoir (Cheyenne River at Edgemont, Hat Creek near Edgemont, Cascade Springs near Hot Springs, and Horsehead Creek at Oelrichs) showed average inflow to be about 90,000 AF/year (124.3 cfs). This is a close approximation of adjusted computed reservoir inflows based on actual elevations and measured releases of 89,500 AF/year. Under normal conditions, 60-80% of the runoff occurs during late spring and summer. A 1953-1997 period of record was retrieved from HYDROMET databases to compute monthly inflows for the reservoir, incorporating evaporation and precipitation. Net inflows were computed to average 82,520 AF/year (114 cfs), which took into account an average of 10 cfs evaporation from the reservoir.

Reservoir Storage

Reservoir storage has decreased due to the natural buildup of sediment. Sediment surveys were done in 1965 and 1979 from which area-capacity tables were developed. The latest area-capacity table (done in 1981) showed an active conservation capacity of 82,443 AF between minimum elevation 3163.0 feet and maximum elevation 3187.2 feet, with a total capacity of 130,768 AF (Table 3.3 and figure 3.2). About 29,000 AF of storage have been lost since construction of the dam (Table 3.3). Inactive storage is 39,700 AF between elevations 3139.75 feet (invert of the lowest river outlet) and 3163.0 feet. Dead storage below elevation 3139.75 feet is 8,598 AF. Surcharge capacity is 56,360 AF between elevations 3187.2 feet and 3198.1 feet, the maximum water surface. (Appendix D shows reservoir capacity allocations, Appendix E area-capacity tables and curves.)

Tables 3.4 and 3.5 show monthly reservoir EOM contents and corresponding elevations, respectively, for 1953-1997. Content was obtained from HYDROMET water year database and then converted to a calendar-year database. The average EOM content was 112,100 AF at elevation 3179.83 feet, with the highest annual average storage of 147,600 AF occurring in 1963, the lowest annual average of 67,900 AF in 1989. The maximum monthly

Table 3.3: 1949, 1966, and 1981 Area-Capacity/Allocation Table

		1949 Original			October 1966			September 1981		
	Elevation (ft)	Capacity Allocation	Capacity (AF)	Area (Acres)	Capacity Allocation	Capacity (AF)	Area (Acres)	Capacity Allocation	Capacity (AF)	Area (Acres)
Streambed at dam axis	3062.0		0.0	0.0		0.0	0.0		0.0	0.0
	3070.0		16.0	42.0		0.0	0.0		0.0	0.0
	3075.0		142.0	18.0		0.0	0.0		0.0	0.0
	3080.0		230.0	22.0		0.0	0.0		0.0	0.0
	3090.0		659.0	77.0		0.0	0.0		0.0	0.0
	3100.0		1,723.0	152.0		0.0	0.0		0.0	0.0
	3110.0		3,725.0	266.0		0.0	0.0		0.0	0.0
	3115.0		5,236.0	340.0		12.0	4.0		0.0	0.0
	3120.0		7,167.0	441.0		39.0	30.0		7.0	3.0
	3125.0		9,825.0	630.0		488.0	110.0		187.0	69.0
	3130.0		13,482.0	835.0		2,253.0	610.0		1,047.0	275.0
	3135.0		18,235.0	1,065.0		6,275.1	980.0		3,957.0	889.0
Top of Dead/ River outlet invert	3139.75	23,740.3	23,740.3	1,250.3	11,223.6	11,223.6	1,094.0	8,598.0	8,598.0	1,064.8
	3140.0		24,030.0	1,260.0		11,484.0	1,100.0		8,865.0	1,074.0
	3145.0		31,118.0	1,580.0		17,640.0	1,380.0		14,737.0	1,275.0
	3150.0		39,669.0	1,840.0		25,310.0	1,700.0		21,717.0	1,517.0
	3155.0		49,677.0	2,170.0		34,672.0	2,000.0		30,505.0	1,998.0
Top of spillway crest	3157.2		54,835.6	2,324.0		39,406.0	2,154.0		35,041.0	2,125.6
	3160.0		61,401.0	2,520.0		45,431.0	2,350.0		41,220.0	2,288.0
Top of inactive/ Canal outlet	3163.0	45,727.2	69,467.4	2,724.0	41,607.8	52,831.4	2,500.0	39,727.0	48,325.0	2,448.8
	3165.0		74,845.0	2,860.0		57,765.0	2,600.0		53,330.0	2,556.0
Minimum recreation pool	3170.0	20,614.6	90,082.0	3,245.0	19,477.6	72,309.0	3,170.0	18,625.0	66,950.0	2,892.0
	3175.0		107,474.0	3,720.0		88,718.0	3,450.0		82,472.0	3,317.0
	3180.0		127,307.0	4,210.0		107,552.0	4,050.0		100,417.0	3,861.0
	3185.0		149,471.0	4,650.0		128,563.0	4,420.0		120,920.0	4,340.0
Top of active conservation/ Top of spillway gates	3187.2	90,451.6	159,919.0	4,841.0	85,928.6	138,760.0	4,706.0	82,443.0	130,768.0	4,612.0
	3190.0		174,050.0	5,080.0		152,478.0	5,080.0		144,167.0	4,959.0
	3195.0		200,470.0	5,490.0		178,888.0	5,490.0		170,107.0	5,417.0
Top of surcharge/ Maximum water surface	3198.1	56,300.0	216,219.0	5,564.0	56,300.0	195,060.0	5,564.0	56,360.0	187,128.0	5,564.0

Source: 1949 original area-capacity table and 1966 and 1981 area-capacity tables computed from sediment resurvey of 1965 and 1979.

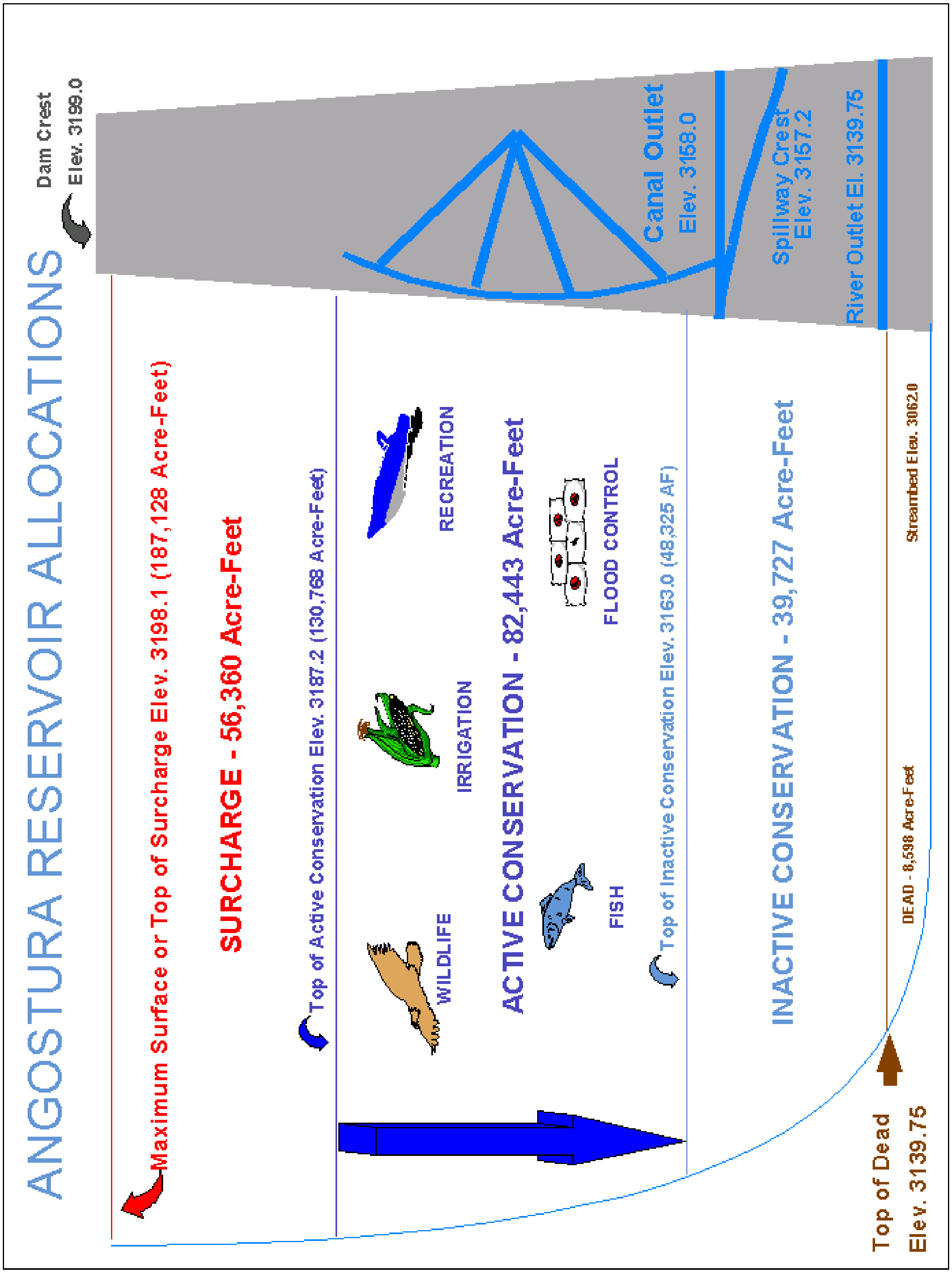

ANGOSTURA RESERVOIR ALLOCATIONS
Dam Crest
Elev. 3199.0
Maximum Surface or Top of Surcharge Elev. 3198.1 (187,128 Acre-Feet)
SURCHARGE - 56,360 Acre-Feet
Top of Active Conservation Elev. 3187.2 (130,768 Acre-Feet)
WILDLIFE
IRRIGATION
RECREATION
FISH
FLOOD CONTROL
ACTIVE CONSERVATION - 82,443 Acre-Feet
Canal Outlet
Elev. 3158.0
Top of Inactive Conservation Elev. 3163.0 (48,325 AF)
Spillway Crest
Elev. 3157.2
INACTIVE CONSERVATION - 39,727 Acre-Feet
River Outlet El. 3139.75
Top of Dead
Elev. 3139.75
DEAD - 8,598 Acre-Feet
Streambed Elev. 3062.0

Table 3.4: Monthly Reservoir EOM Contents, 1953-1997 (1,000 AF)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Average	105.9	109.4	117.4	121.7	126.6	126.1	117.4	107.3	102.4	102.4	103.5	104.6	112.1
Minimum	65.7	67.8	70.6	72.1	77.5	73.5	65.9	56.9	60.4	61.2	62.8	64.3	67.9
10-percentile	74.0	80.9	87.9	89.1	100.2	95.8	82.5	71.9	70.0	70.6	71.5	72.7	85.4
Median	102.6	109.0	120.3	129.6	130.0	129.5	117.8	106.9	99.6	100.7	102.6	101.5	113.0
90-percentile	132.2	137.1	138.4	142.1	157.9	158.9	147.7	142.0	135.1	129.6	129.9	129.9	134.5
Maximum	148.1	153.2	160.0	160.3	162.2	160.2	160.2	155.7	160.0	155.5	150.7	149.6	147.6

Source: HYDROMET data—see Appendix F.

Table 3.5: Monthly Reservoir EOM Elevations, 1953-1997 (Feet)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Average	3178.3	3179.2	3181.2	3182.2	3183.4	3183.3	3181.2	3178.6	3177.3	3177.5	3177.8	3178.1	3179.8
Minimum	3164.4	3164.9	3165.5	3165.8	3166.1	3166.3	3164.7	3163.6	3162.9	3163.1	3163.4	3163.9	3164.8
10-percentile	3170.1	3170.7	3172.7	3173.5	3177.0	3177.1	3174.1	3170.2	3168.5	3168.7	3169.1	3169.6	3173.9
Median	3179.3	3179.8	3182.5	3184.2	3186.0	3186.1	3183.8	3179.9	3178.3	3178.5	3178.9	3179.4	3181.7
90-percentile	3185.4	3186.7	3187.0	3187.1	3187.2	3187.2	3186.7	3185.5	3184.0	3184.4	3184.7	3185.0	3184.3
Maximum	3185.8	3187.0	3187.2	3187.2	3187.6	3187.3	3187.2	3186.3	3187.2	3186.2	3185.4	3185.3	3185.7

Source: HYDROMET data—see Appendix F.

EOM content of 162,200 AF at elevation 3187.6 feet occurred in May 1962, the minimum of 56,900 AF in August 1989. The monthly minimum EOM elevation of 3162.92 feet occurred September 1960. (Appendix F contains the HYDROMET database and AGRAOP EOM contents and elevations based on adjusted inflows.)

Reservoir Releases to the District

The District's water demands depend on the acres irrigated and the CIR (crop irrigation requirement). CIR was estimated to be 18.74 inches/acre based on the Modified Blaney-Criddle Method. District records for 1993 show a cropping pattern of 50% alfalfa, 38% corn, 8% pasture, 3% grain, and 1% beans; this pattern was used in the analysis.

Table 3.6 shows monthly releases to the District based on HYDROMET data, including District records from 1955 (when they began irrigating) to 1997, showing an annual average release to the main canal of 40,400 AF/year (55.2 cfs) to irrigate 10,000 acres. Droughts, lack of carry-over storage, and unirrigated lands (such as lands in the Conservation Reserve Program)

Table 3.6: Monthly Reservoir Releases to the District, 1955-1997 (cfs)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Ann.
Average	0.0	0.0	0.0	4.5	53.6	74.5	208.0	213.4	97.9	10.0	0.0	0.0	55.2
Minimum	0.0	0.0	0.0	0.0	0.0	3.4	112.2	68.3	0.0	0.0	0.0	0.0	16.4
10-percentile	0.0	0.0	0.0	0.0	2.0	21.8	134.0	156.1	52.4	0.0	0.0	0.0	43.0
Median	0.0	0.0	0.0	0.0	53.7	62.2	221.2	222.8	97.5	0.0	0.0	0.0	55.6
90-percentile	0.0	0.0	0.0	15.1	93.7	135.5	262.2	267.4	139.2	33.5	0.0	0.0	66.1
Maximum	0.0	0.0	0.0	45.4	117.1	218.5	287.9	299.2	191.6	65.1	1.7	0.0	81.0

Source: HYDROMET database–see Appendix G.

cause less than the 12,218 acres contracted for to be irrigated. Annual median canal flows are 40,700 AF (55.6 cfs) at present, almost the same as the annual average. Maximum monthly releases of 18,400 AF (299.2 cfs) occurred in August 1959, the minimum of zero during some months in the normal irrigation season. The highest annual release of 59,100 AF (81.0 cfs) occurred in 1958, while the lowest of 12,100 AF (16.4 cfs) occurred in 1961, reflecting record minimal inflows of 19,000 AF (26.1 cfs). (Appendix G gives canal releases by month.)

Reservoir Releases to the River

Annual average river release is 59.9 cfs (43,400 AF), with the highest annual average of 406.7 cfs (294,500 AF total) occurring in 1962, the lowest annual average of zero in both 1976

Table 3.7: Monthly Reservoir Releases to the River, 1953-1997[1] (cfs)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Ann.
Average	10.2	20.3	66.0	38.7	183.7	280.3	75.3	18.9	6.1	4.8	6.6	7.9	59.9
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Median	0.0	0.0	0.0	1.7	8.1	13.4	1.6	0.0	0.0	0.0	0.0	0.0	29.5
90-percentile	47.5	76.0	160.4	123.0	527.9	803.6	192.6	52.3	8.4	12.7	23.9	37.1	177.4
Maximum	117.1	212.5	673.3	369.7	2384.2	2825.0	1229.5	198.4	95.8	58.5	89.1	84.6	406.7

Source: HYDROMET database—see Appendix G.

and 1977 (Table 3.7). Annual median flow is 29.5 cfs (20,600 AF), about half the annual average. USGS records (1998) show the highest daily average of 20,600 cfs occurred June 18, 1962, with an instantaneous peak flow of 30,300 cfs on May 20, 1978. Uncontrolled releases occur when reservoir capacity reaches elevation 3187.2 feet (the top of spillway gates). Seepage past the dam's radial gates is small, normally about 3.3 cfs (200 AF/month).

Estimated monthly river flows at the Buffalo Gap gauge 40 river miles downstream are shown in Table 3.8. They represent reservoir releases combined with accretion and return flows. Flows at Buffalo Gap are assumed to approximate flows at Red Shirt, about 10 river miles further downstream.

Accretion and Return Flows

*Accretion flow*s join the river from tributaries, springs, and the District. Table 3.9 shows accretion flows from the reservoir downstream to the Buffalo Gap gauge, including Fall River and Beaver Creek inflows measured at the gauges and estimated inflows from ungauged areas based on measured flows at Hat Creek.

Table 3.9 also shows estimated average annual *return flows* from the District, the remaining irrigation water returning to the river after consumption by crops and recharge to groundwater. District return flows are estimated to be 54% of releases to the canal, or about 30 cfs. Estimated return flows of 2 cfs are included from irrigation along Beaver Creek. The only outflows in the table are for evapotranspiration from the stream corridor.

Table 3.9: Accretion/Return Flows Between the Dam and the Buffalo Gap Gauge, 1955-1997[1] (cfs)

Sources	Flows (cfs)
Fall River	23
Beaver Creek	7
Beaver Creek Return Flows	2
Ungauged Flows	8
District Return Flows	30
Evapotranspiration from Stream Corridor	-4
Total Accretions	66

[1] Appendix J shows how accretion and return flows were calculated.

Table 3.8: Estimated Monthly Flows at the Buffalo Gap Gauge, 1955-1997[1] (cfs)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Ann.
Average	60.5	79.5	133.8	99.7	262.1	382.6	129.5	68.8	71.4	79.9	72.5	70.6	125.9
Minimulm	47.8	56.3	53.1	44.1	45.7	47.5	41.2	48.2	60.8	57.6	60.7	59.7	55.8
10-percentile	50.7	58.1	56.9	48.9	48.0	50.5	45.3	50.3	63.7	61.6	62.9	60.8	57.5
Median	53.2	61.7	65.5	67.8	74.7	69.2	59.5	55.6	69.3	68.7	67.0	64.2	96.9
90-percentile	76.9	120.7	227.1	192.7	733.2	945.8	238.3	77.6	74.8	89.4	98.5	88.4	256.2
Maximum	145.5	283.9	736.6	433.9	2475.5	2950.8	1312.1	254.7	163.5	415.3	155.2	158.2	475.6

[1] Appendix J shows the water budget analysis done in cooperation with USGS.

SURFACE WATER QUALITY

The public asked that possible contaminants from grazing, recreation, oil wells, the bombing range on the Pine Ridge Reservation, and mining be analyzed in this EIS, in sediment, aquatic life, and in the water itself. Reclamation added other water quality considerations to be examined.

Information from many sources was used to characterize water quality. Two U.S. Department of the Interior studies describe water quality in the Cheyenne River basin. In 1988, the NIWQP (National Irrigation Water Quality Program) studied the Angostura Unit's effects on water quality and biota (Greene et al. 1990). Sampling included water and sediment samples from Angostura Reservoir. Since South Dakota was undergoing a drought in 1988, NIWQP did a Verification Study in 1994 on water quality aspects of the earlier study; it has not been published yet, but data were provided by USGS (Joyce Williamson 1999: personal communication). The EPA (Environmental Protection Agency) collected data from the reservoir and river in 1974 as part of the NES (National Eutrophication Survey).

The SDDENR (South Dakota Department of Environment and Natural Resources) has sampled the reservoir each year since 1989 (except for 1990). Data collected included temperature, DO (dissolved oxygen) profiles, *Secchi* depths (a measurement of the depth to which a disk put into water can be seen), nutrient species, and total suspended solid concentrations from surface and bottom samples. The SDDENR published temperature and DO profiles measured from 1991-1994 (Stueven and Stewart 1996).

The OST (Oglala Sioux Tribe) monitored water quality of the Cheyenne River near Red Shirt from 1993-1997 (Hoof 1998). They supplied data to supplement NIWQP data. The CRST (Cheyenne River Sioux Tribe) sponsored a USGS study of water quality trends in the Cheyenne and Moreau Rivers (Heakin 1998). Water and fish were sampled in July and August 1997 (Plateau 1998). This information was provided for the EIS. The CRST have also undertaken a sediment monitoring study of the Cheyenne and Moreau rivers funded by EPA; contaminant data have been provided for the EIS.

Reclamation sampled the reservoir and the river for DO, TDS (total dissolved solids, or salts), major ions, trace elements, and pesticides in 1997 and 1998. Sites upstream of the reservoir were sampled as were sites down to Cherry Creek on the Cheyenne River Sioux Reservation. These samples included water, bed sediment, and fish.

Angostura Reservoir

Reservoirs and lakes go through a natural aging process wherein they are transformed from a lake into a marsh, and then into a meadow. This gradual process can be accelerated by an increase of nutrients and sediments. When determining status of a reservoir, a set of trophic states are used:

- *Oligotrophic* or low in nutrients
- *Mesotrophic* or moderate in nutrients
- *Eutrophic* or high in nutrients
- *Hypereutrophic* or very high nutrients.

The *Clean Lakes Report* (South Dakota Department of Environment and Natural Resources 1996) categorized Angostura Reservoir as mesotrophic, with a declining trend in water quality: "Major pollution sources of the reservoir, however, were categorized as natural" (p. 5). A trend line in that report based on the trophic State index for the last decade indicated a trend towards oligotrophy, or improving water quality.

One of the effects of eutrophication is more algal growth which decreases water clarity, can cause odor and taste problems, and can increase toxicity to fish and invertebrates. Oxygen and carbon dioxide levels are also directly affected by plant activity, which, in turn, are related to health of aquatic species. Since most aquatic organisms require oxygen for survival, DO is often used to evaluate general health of reservoirs and streams. It can be depleted to the point where the bottom of a reservoir is completely without oxygen.

Most reservoirs are also subject to seasonal changes. Ice cover with a relatively constant temperature from surface to bottom is typical in winter. As temperatures rise in the spring, ice melts and the surface warms up. Even slight winds result in mixing of the water while the water temperature is uniform. A temperature gradient develops as summer progresses where the surface of the reservoir is much warmer than the bottom, and a thermocline exists where water changes dramatically from warm to cold. In the late summer, surface water begins to cool. It becomes more dense as a result and sinks towards the bottom of the reservoir. When water temperature becomes the same from top to bottom, the fall *turnover*, or complete mixing, takes place.

As mentioned before, Angostura Reservoir was surveyed for the NES in 1974; sampling was repeated in 1978 and again from 1989-1995 by SDDENR. Data from these studies show similar conditions: Elevated nitrogen, phosphorus, and chlorophyll, indicative of eutrophication of the reservoir. In late summer, DO was depressed at depth, but complete oxygen depletion did not occur. The reservoir was also relatively saline, or high in dissolved solids. It was well mixed (little or no difference in water temperature with depth) and DO was near saturation in April. The thermal stratification was well established by July, with the thermocline between 30-40 feet deep. DO decreased below that depth. In September, the cooling reservoir returned to a nearly fully mixed temperature profile, although there was lingering depression of DO.

Temperature and DO samples collected by SDDENR in the spring, summer, and fall in 1978, 1989-1990, and 1992-1995 indicated the reservoir tended to be stratified from June-August (figure 3.3). The minimum bottom DO occurred in August, with measurements of less than 1 mg/L (milligram/liter). Fall turnover occurred during early to mid-September.

Cheyenne River

Dissolved Oxygen

DO in water is not constant, affected as it is by temperature, air pressure, and biology. A calculated DO concentration for a given temperature and barometric pressure is used with a measured DO concentration to produce a percent of saturation. This value can be used to evaluate stream health since it takes into account both changes in temperature and air pressure.

EPA recommends 3 mg/L as the instantaneous minimum DO concentration for adult warmwater fish like those in the Cheyenne River. South Dakota has designated stream reaches for specific beneficial uses and has established standards necessary to support the uses. The Cheyenne River from the Wyoming border to Lake Oahe is designated by the State for *Warmwater Permanent* or *Warmwater Semi-permanent Fish Life Propagation* (depending on the section of river), *Immersion Recreation*, *Limited Contact Recreation*, *Wildlife Propagation and Stock Watering*, and *Irrigation Waters*. State standards specify DO should be greater than 5 mg/L to maintain designated uses.

The OST are reviewing streams—including the Cheyenne River where it borders the Reservation—to likewise determine beneficial uses and standards. Uses will probably parallel

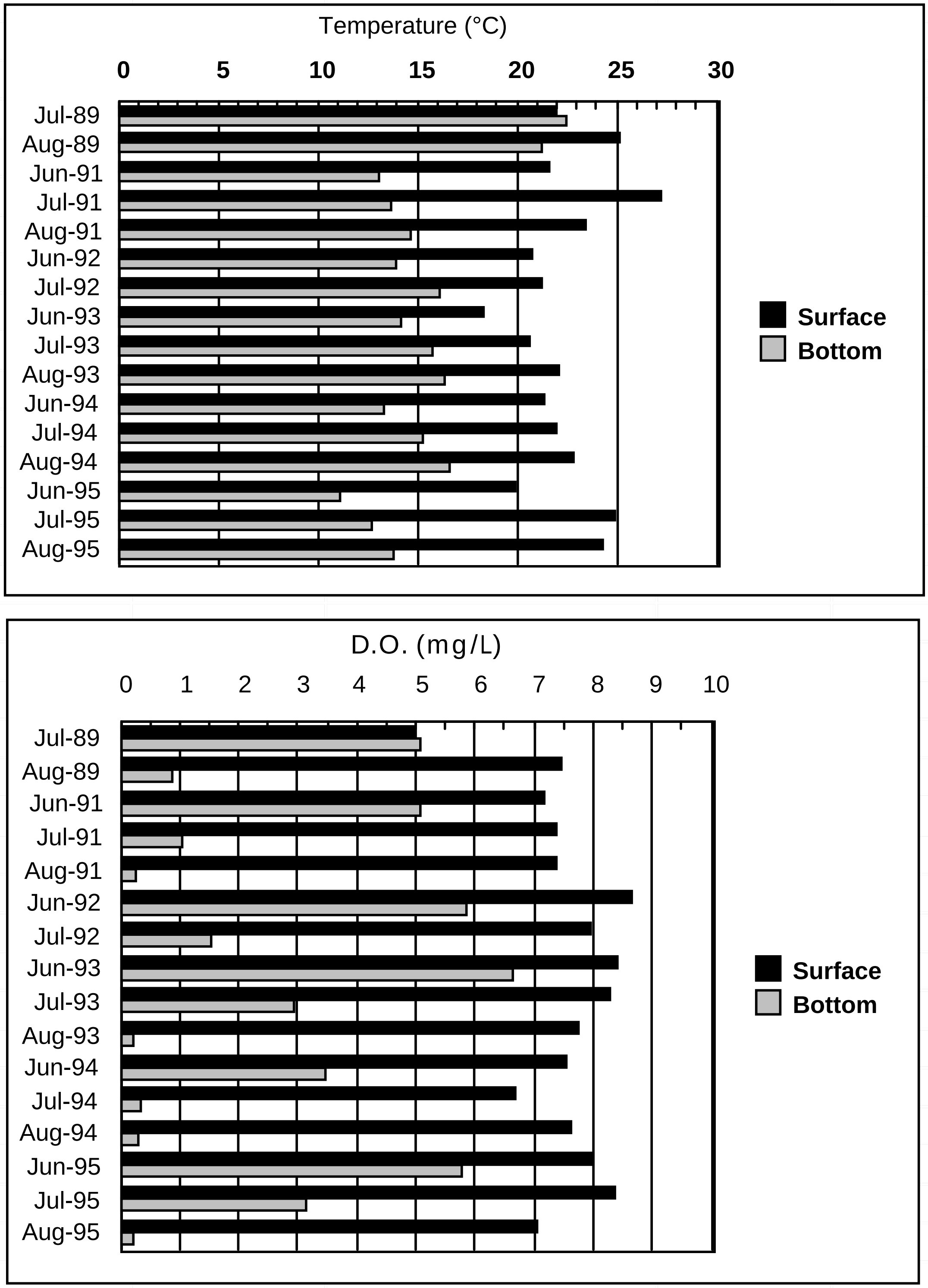


Figure 3.3: Reservoir Surface and Bottom Temperatures/DO, Summer 1989-1995

those of the State, while standards will probably meet or exceed State standards (Kim Clausen 2000: personal communication).

DO concentrations in the river and reservoir from NIWQP sampling, the OST study, and the CRST studies are listed in Table 3.10. Percent saturation was available for the Verification Study and the OST study, while it was estimated for NIWQP sampling and the CRST sediment monitoring study from temperatures and estimated barometric pressure of 680 mm (millimeters) of mercury.

Table 3.10 shows periodic low DO in the river: DO for December 1993 and May 1996, for example, was at 10% and 8% saturation, respectively. The December 1993 reading would correspond to about 1.5 mg/L DO, while that for May 1996 would correspond to about 0.8 mg/L. Other than these two readings, no DO concentrations were found to be less than 5 mg/L. There is no way to estimate frequency or duration of low DO episodes, however, from the limited data available.

Total Dissolved Solids

Another simple and effective measure of water quality is specific *EC* (electrical conductance). EC measures the capacity of water to conduct electricity, and specific electrical conductivity is the conductance at a specific temperature of a 1-centimeter cross-sectional area (the standard temperature is 25º C, so field measurements are adjusted to account for temperature changes). Since EC measures the electricity conducted, it is generally proportional to concentrations of TDS in the water. Pure water is a very poor conductor; as dissolved solids increase, EC of the water increases.

TDS can be used to measure effects of irrigation on water quality. TDS in irrigation water, after plant consumption and evaporation, can become concentrated in return flows. The effects of irrigation thus can be measured by increases in TDS downstream of the irrigated area, or in return flows.

TDS, as mentioned before, is equivalent to salts found in water. Major ions that make up TDS include calcium, magnesium, sodium, potassium, sulfate, chloride, and bicarbonate. The water immediately above Angostura Reservoir is predominately a calcium-sulfate type, while downstream of the reservoir it becomes a calcium-sodium-sulfate type.

Generally, calcium, sodium, and sulfate concentrations progressively increase from upstream to downstream. NIWQP data showed TDS concentrations decreased from upstream to immediately downstream of the reservoir, and then progressively increased thereafter. A salt budget on the Cheyenne River and tributaries, based on information from 1979-1980 (years with the most complete geographic information available), showed similar results (Table 3.11). TDS concentrations in return flows from the District were similar to concentrations measured upstream at the Edgemont gauge.

During low-flow years, upstream concentrations generally were higher, diluted by mixing in the reservoir, and then increasing again below the dam. When flows were normal to high in 1997, TDS concentrations generally were lower. Calcium concentrations increased from above the reservoir to near Custer County Bridge 656, then decreased again. Sodium in 1997 stayed relatively constant, and sulfate followed a pattern similar to sodium. The decrease in calcium and sulfate near the Custer County Bridge and Cherry Creek could be due to dilution from Beaver Creek, Cottonwood Creek, French Creek, Spring Creek, and Rapid Creek, tributaries to the river (see figure 3.1).

Table 3.10: DO/Saturation in the Cheyenne River

Study	Site	Date	DO (mg/L)	Saturation (%)
NIWQP	River near Hot Springs	5/4/88	7.6	96.2
NIWQP	River near Hot Springs	6/22/88	7.2	104.0
NIWQP	River near Hot Springs	8/22/88	7.9	108.0
NIWQP	River near Hot Springs	11/1/88	8.8	98.9
NIWQP	Horsehead Creek at Oelrichs	5/5/88	9.0	108.0
NIWQP	Angostura Reservoir	5/4/88	1.3	13.5
NIWQP	Angostura Reservoir	6/23/88	7.6	96.2
NIWQP	Angostura Reservoir	11/1/88	9.1	90.1
NIWQP	Fall River at mouth	5/5/88	9.9	118.0
NIWQP	Fall River at mouth	6/23/88	6.4	95.5
NIWQP	Fall River at mouth	8/24/88	8.4	112.0
NIWQP	Fall River at mouth	11/3/88	9.8	109.0
NIWQP	River above Buffalo Gap	5/3/88	9.8	110.0
NIWQP	River above Buffalo Gap	6/21/88	6.0	84.5
NIWQP	River above Buffalo Gap	8/23/88	7.9	94.0
NIWQP	River above Buffalo Gap	11/2/88	10.4	103.0
NIWQP	Iron Draw near Buffalo Gap	5/6/88	8.5	101.0
NIWQP	Iron Draw near Buffalo Gap	6/21/88	7.8	110.0
NIWQP	Iron Draw near Buffalo Gap	8/23/88	8.0	101.0
NIWQP	Iron Draw near Buffalo Gap	11/2/88	9.2	100.0
NIWQP	Cottonwood Creek near Buffalo Gap	5/3/88	10.1	107.0
NIWQP	Cottonwood Creek near Buffalo Gap	6/24/88	2.8	35.9

Table 3.10: DO/Saturation in the Cheyenne River (Continued)

Study	Site	Date	DO (mg/L)	Saturation (%)
NIWQP	Cottonwood Creek near Buffalo Gap	8/24/88	3.1	34.8
NIWQP	Cottonwood Creek near Buffalo Gap	11/2/88	7.2	71.3
NIWQP	River near Fairburn	5/6/88	6.6	82.5
NIWQP	River near Fairburn	6/20/88	9.4	142.0
NIWQP	River near Fairburn	8/26/88	8.9	109.0
NIWQP	River near Fairburn	10/31/88	11.2	110.0
Verification Study	River at Edgemont	4/19/94	9.1	103.0
Verification Study	River at Edgemont	9/8/94	7.6	107.0
Verification Study	River downstream of Dam	4/19/94	11.8	120.0
Verification Study	River downstream of Dam	9/9/94	8.3	104.0
Verification Study	River near Bridge 656	4/20/94	9.2	101.0
Verification Study	River near Bridge 656	9/8/94	8.8	107.0
Verification Study	River near Fairburn	4/20/94	9.6	110.0
Verification Study	River near Fairburn	9/8/94	8.7	102.0
OST	CRI	12/12/93	1.5	10.1
OST	CRI	5/25/95		87.1
OST	CRI	5/15/96	0.8	8.0
OST	CRI	9/30/96		32.8
OST	CRI	7/1/97		90.5
OST	CRI	10/16/97		82.0
OST	CRII	7/16/97		71.9
OST	CRII	10/1/97		86.9
CRST	CR1	7/28/97 - 8/3/97	9.0	114.0
CRST	CR2	7/28/97 - 8/3/97	9.1	126.0
CRST	CR3	7/28/97 - 8/3/97	11.8	157.0
CRST	CR4	7/28/97 - 8/3/97	10.5	146.0

The OST sampled the river in May or June for 5 years when flows were high, and again in the fall or winter when flows were low. These samples showed concentrations changing, with lower concentrations during high flows and higher concentrations during low flows. This generally is what would be expected for most constituents due to dilution.

An analysis along the river's lower reach found upward trends in sulfate, chloride, and TDS over time (Heakin 1998). EPA's 250 mg/L SMCL (secondary maximum contaminant level) for sulfate was exceeded, as was the 500 mg/L level for TDS. The Cheyenne River is not designated for human consumption, although it may be used for that purpose; drinking water standards are included in this section only as a means of comparison.

Trace Elements

Trace or minor elements are solids dissolved (or held as very small particulates) in water, generally at concentrations of less than 1 mg/L (Hem 1985). Although trace elements occur at low concentrations, they can significantly affect the aquatic environment and human health.

The NIWQP study found elevated trace elements in several Cheyenne River tributaries. Findings from the NIWQP study and the Verification Study—as well as the Reclamation and OST studies—are shown in Table 3.12. These findings are compared to South Dakota Aquatic Life standards, when available, or to South Dakota Human Health standards or EPA MCLs (maximum contaminant levels) or secondary MCLs otherwise.

MCLs are based on total recoverable concentrations, so comparisons in the table are conservative since total concentrations are greater than, or equal to, dissolved concentrations. Also, some of the aquatic life standards vary with water hardness: The findings in the table are based on 100 mg/L hardness as presented in the *State Water Quality Standards: Appendix B*. Water in the area is generally very hard, with concentrations from 500-1,800 mg/L. Higher standards are applied to hard water because aquatic organisms can tolerate higher levels of trace elements at a higher hardness.

The OST study found antimony concentrations ranging from 220-360 µg/L (micrograms/liter), which exceeded drinking water standards (Table 3.12). The 4 µg/L cadmium found at Fall River and the 5 µg/L cadmium at Cheyenne River above Buffalo Gap are below both aquatic life acute and chronic standards based on hardnesses of 560 and 780 mg/L, respectively, the day the samples were collected. Fall River was a background site in the NIQWP study, and the Cheyenne River site receives return flows. Neither antimony nor cadmium are characteristic of irrigation return flows.

A copper concentration of 11 µg/L collected at the District canal didn't exceed the aquatic chronic standard of 67 µg/L based on a hardness of 800 mg/L. Lead concentrations from the NIWQP study didn't exceed the hardness-adjusted standards of 22-17 µg/L. Reclamation's study also reported a lead concentration of 5 µg/L from the Cheyenne River at the Cherry Creek site. Lead is not associated with return flows.

A mercury concentration of 5.3 µg/L at Cheyenne River above Buffalo Gap exceeded the aquatic acute and chronic standards of 2.4 and 0.012 µg/L, respectively. This could be the result of sample contamination, however, or an error at the laboratory analyzing the samples (Greene et al. 1990).

Several selenium concentrations at Iron Draw near Buffalo Gap and Cottonwood Creek near Buffalo Gap exceeded the aquatic chronic standard of 5 µg/L. At the time of the NIWQP study, the chronic standard was 10 µg/L, and only the two Cottonwood Creek samples exceeded it.

Table 3.11: Annual TDS Concentrations, Total Salt Loads, and Flows (1979-1980)

Site	Cheyenne River			Tributaries		
	1979			1979		
	TDS (mg/L)	Flows (AF)	Load (Tons)	TDS (mg/L)	Flows (AF)	Load (Tons)
Cheyenne at Edgemont	2,300	61,100	134,420			
Cheyenne at Dam	1,705	20,000	44,380			
Fall River				962	16,000	21,160
Beaver Creek				2,041	5,700	15,550
Cheyenne at Buffalo Gap	1,973	66,368	170,850			
Rapid Creek				604	33,300	27,400
Cheyenne at Wasta	1,396	168,500	292,190			
Belle Fourche River				1,945	160,200	319,400
Cheyenne at Plainview	1,436	322,700	588,520			
Cheyenne at Cherry Creek	1,782	350,400	731,980			
	1980			1980		
Cheyenne at Edgemont	2,996	32,800	119,850			
Cheyenne at Dam	1,767	17,900	45,870			
Fall River				1,025	15,400	21,690
Beaver Creek				2,165	4,300	12,030
Cheyenne at Buffalo Gap	2,124	55,171	160,280			
Rapid Creek				646	28,500	24,380
Cheyenne at Wasta	1,500	96,500	196,450			
Belle Fourche River				2,085	79,000	193,830
Cheyenne at Plainview	1,599	174,000	358,080			
Cheyenne at Cherry Creek	1,883	184,000	428,260			

Table 3.12: Dissolved Trace Elements in the River Near the District (µg/L)

	Criteria	Standard	NIWQP	Verification	Reclamation	OST
Aluminum	EPA SMCL	50-200 µg/L				<100 - 100
Antimony	SD Human Health	4,300 µg/L[1]				220 -360
Arsenic	SD Human Health	0.14 µg/L[1]	<1 - 4	<1 - 2	<1 - 6	<100 - 100
Barium	EPA MCL	2,000 µg/L				70 - 80
Boron	None		180 - 650	160 - 1,100	193 - 359	160 - 190
Cadmium	SD Aquatic Acute Chronic	 3.7 µg/L[2] 1.0 µg/L[2]	<1 - 5	<1 - <1	0.2 - 0.2	<10 - <10
Chromium[3]	SD Aquatic Acute Chronic	 15 µg/L 10 µg/L	<1 - 4	<1 - <1	<1 - 4	20 - 30
Copper	SD Aquatic Acute Chronic	 17 µg/L [2] 11 µg/L [2]	<1 - 11	<0.1 - 1	<1 - 9	<10 - <10
Iron	EPA SMCL	300 µg/L				10 - 15
Lead	SD Aquatic Acute Chronic	 65 µg/L[2] 2.5 µg/L[2]	<5 - 11	<1 - <1	<1 - 5	<50 - <50
Manganese	EPA SMCL	50 µg/L				<10 - <10
Mercury	SD Aquatic Acute Chronic	 2.1 µg/L 0.012 µg/L	<0.1 - 5.3	<0.1 - <0.1	<0.2 - 0.2	<1 - <1
Molybdenum	None		<1 - 16	4 - 8	<1 - 8	10 - 200
Nickel	SD Aquatic Acute Chronic	 1400 µg/L [2] 160 µg/L [2]				10 - 20
Selenium	SD Aquatic Acute Chronic	 20 µg/L 5 µg/L	<1 - 16	<1 - 4	<1 - 2.1	
Silver	SD Aquatic Acute Chronic	 3.4 µg/L[2] none				<10 - 10
Uranium	EPA MCL	20 µg/L [4]	3.9 - 44	7.6 - 25	1 - 34	
Vanadium	None		<1 - 6	2 - 15	1 - 21	
Zinc	SD Aquatic Acute Chronic	 110 µg/L[2] 100 µg/L[2]	<10 - 76	<10 - 5	5 - 20	<10 - <10

Sources: South Dakota Department of Environment and Natural Resources 1998; EPA 1996.

[1] Based on one route of exposure—ingestion of contaminated aquatic organisms only.

[2] Based on a $CaCO_3$ hardness of 100 mg/L.

[3] Standard based on Chromium VI; dissolved chromium in the river would mostly be in this form.

[4] Equivalent to 15 pCi/L.

It should be noted that Cottonwood Creek was a background site in the NIWQP study and that selenium is common in the marine shale soils of the area.

The CRST study measured *total* trace elements—less biologically available than dissolved trace elements—in the river downstream of the Belle Fourche River, outside of the influence of the District. The range of findings is shown in Table 3.13. These values are not comparable to the aquatic standards, since the latter are based on dissolved concentrations.

Table 3.13: Total Trace Elements in the River (mg/L)

Trace Element	Range
Arsenic	0.005-0.052
Barium	0.04-0.83
Cadmium	<0.0005-0.0005
Chromium	<0.010-0.016
Copper	<0.10-0.024
Iron	0.42-19.80
Lead	<0.002-0.006
Manganese	0.04-0.35
Mercury	<0.0002-0.0019
Nickel	<0.005-<0.030
Selenium	0.002-0.005
Silver	<0.005-<0.010
Zinc	<0.02-216.0

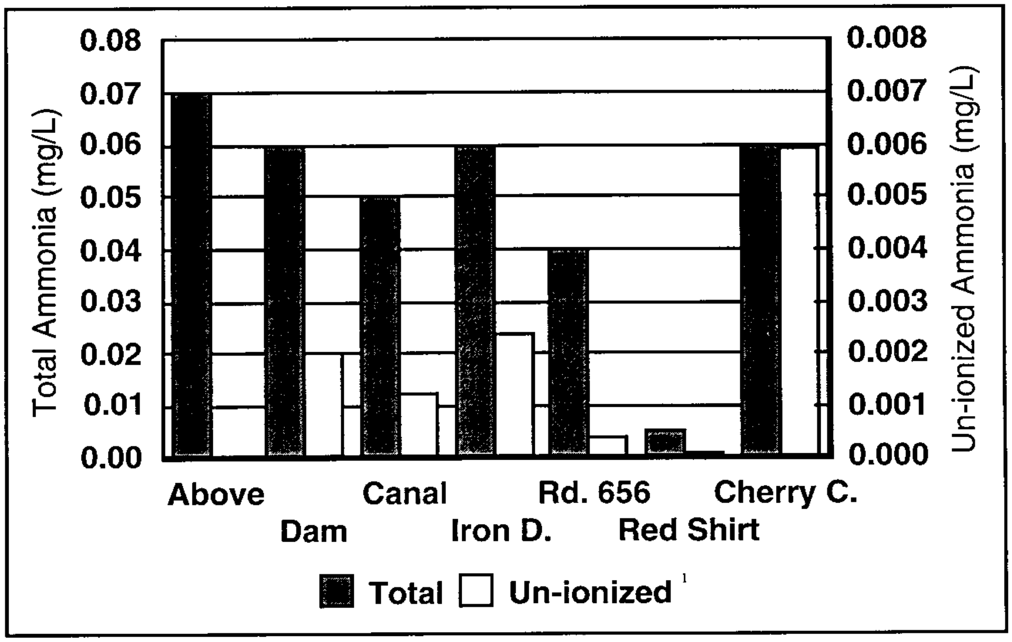
Results of the 1988 NIWQP sampling indicate that return flows had relatively low concentrations of trace elements. Greene et al. (1990) concluded that "there appeared to be minor difference between concentration of trace elements in water of the Cheyenne River upstream of irrigated land and in water downstream from all irrigation return flows" (p. 55).

Nitrogen

Nitrogen can be measured in water as nitrite, nitrate, ammonium, and total *Kjeldahl nitrogen* (that is, nitrogen determined by the Kjeldahl analytical method, which includes organic nitrogen and ammonium). Natural sources—fertilizers, barnyards, confined feedlots, and septic tanks—add nitrogen to the environment. Nitrate is the most common form in water. Because nitrate is highly soluble, fertilizer application followed by heavy rainfall or irrigation can cause transport. Concentrations in drinking water above EPA's MCL of 10 mg/L can cause health problems, especially in pregnant women or children younger than 6 months.

NIWQP samples were analyzed for nitrate plus nitrite (also with an MCL of 10 mg/L). Concentrations found were 1.2 mg/L at Cheyenne River at Buffalo Gap and at 1.3 mg/L at Cheyenne near Fairburn. Reclamation samples generally showed higher concentrations at the Cheyenne River near Hot Springs and at the District's canal. Samples from downstream sites fell within the same range as the NIWQP study, however. The highest concentrations of nitrate plus nitrite were 2.4-4.3 mg/L found at Iron Draw, which was also the only site with a measurable nitrite concentration of 0.3 mg/L.

Total ammonia concentrations were collected at seven sites in the Angostura area in 1997. From these, un-ionized ammonia was calculated based on temperature and pH as shown in figure 3.4.



[1] Un-ionized scale 1/10 of total scale.

Figure 3.4: Ammonia Found at Seven Sites in the Cheyenne River Basin

Un-ionized ammonia can be toxic to aquatic life at 0.02-0.05 mg/L depending on stream temperature. From the figure, it can be seen un-ionized ammonia is only a small proportion of the total ammonia found in the samples. Concentrations are well below the toxic level.

Pesticides

Pesticides—which can be transported in water and thus affect the environment and human health—were sampled at the season of application as part of the original 1988 NIWQP study (Greene et al. 1990). *Atrazine*, *cyanazine*, *prometon*, and *simazine* were the only pesticides found above detectable concentrations.

About half the NIWQP samples reported detectable concentrations of atrazine, with the maximum being 0.2 µg/L. Atrazine is a selective herbicide applied pre- or post-plant to control many broadleaf weeds in corn or sorghum (Ahrens 1994). It is highly soluble but readily decomposed by ultraviolet light (Ahrens 1994). It is classified as slightly toxic. Cyanazine was detected in two NIWQP samples equal to the laboratory reporting limit. The highest concentration for a pesticide was prometon, detected in two samples with a maximum concentration of 1 µg/L.

Simazine, considered practically non-toxic (EXTOXNET 1996), was found in 2 of the 19 NIWQP samples, with both being from samples taken in May. Samples collected from the Cheyenne River near Buffalo Gap contained 0.3 µg/L, while the sample from near Fairburn had a simazine concentration of 0.1 µg/L. EPA's drinking water standard is 4 µg/L.

Reclamation surveyed the District for current information on pesticide use and also sampled six sites in 1997. Atrazine, cyanazine, prometon, and simazinewere sampled for, as well as *alachlor*, *ametryne-gesapax*, *methomyl*, *metribuzin*, *metolachor*, *premetryn*, *propham*, *sevin*, *simetryne*, *treflan*, *aldicarb*, *carbaryl*, *carbofuran*, and *oxamyl* (Appendix Q). None were found above detectable concentrations. Based on these analyses, pesticides in the Angostura area do not appear to exceed acceptable levels.

Edgemont Uranium Mill

The decommissioned Edgemont Uranium Mill lies upstream of the reservoir near the town of Edgemont. The Tennessee Valley Authority bought the mill, tailings, and eight settling ponds in 1974, closing it down in 1978 without ever having operated it. According to the EIS on closing the operation, all contaminated material was buried at the head of an ephemeral drainage 2 miles southeast of the mill, and contaminated sediment and bank material from Cottonwood Creek were removed and buried (U.S. Nuclear Regulatory Commission 1982).

Samples from the upper reach of the Cheyenne River and Cottonwood Creek from 1972-1997 indicated steady decreases in uranium concentrations from 1972-1974. The USGS sampled the Cheyenne River at Hot Springs for uranium four times in 1988, and twice at Edgemont in 1994. The Cheyenne River at Hot Springs gauge being downstream of the mill site should be representative of inflows into the reservoir. The Edgemont gauge, chosen for purpose of comparison, is upstream of both the mill site and Cottonwood Creek.

These samples showed that inflows into the reservoir seem to have been unaffected by any remnant of the uranium operation (Table 3.14). Both the average and maximum levels at Hot Springs were below the EPA drinking water standard for uranium of 15 pCi/L (pico-curies/cubic liter).

Table 3.14: Uranium in the Cheyenne River Upstream of the Reservoir (In pCi/L)

	Edgemont (Above the Mill Site)	Hot Springs (Below the Mill Site)
Average	20.5	8.2
Maximum	25	12

GROUNDWATER

Public concern was expressed about effects of the alternatives on groundwater in the area, and Reclamation was concerned about effects on groundwater recharge from river flows.

A spring and several shallow wells in the District are influenced by irrigation water. The spring, on the eastern end of the District, supplies livestock water to parts of the Buffalo Gap National Grasslands. It predates the District, and—since construction of the canals and irrigation of District lands—the spring has developed into a reliable source of water. It feeds a pond within the District from which water is pumped into a pipeline serving several thousand acres. The pipeline also serves as a wildlife water source.

Figure 3.5 shows the relationship between canal leakage, return flows, and groundwater in the District.

Flows greater than 10,000 cfs could recharge shallow aquifers along the stream corridor below the dam. These larger floods would cause water to spill out of the river channel, which has been cut down to Pierre Shale almost to Wasta. Water on the flood plain could percolate through the alluvium to the aquifers (figure 3.5). Flows less than 10,000 cfs would be confined to the channel, with little chance to recharge the aquifers.

Quantity

Wells in the District are found in shallow alluvium (U.S. Bureau of Reclamation 1996). Surface deposits over much of the irrigated lands are Late Cretaceous-ages marine shales (mostly Pierre Shale) overlain by small areas of alluvial deposits found mainly along the flood plains of Cascade Creek, Fall River, Horsehead Creek, Beaver Creek, Cottonwood Creek, and the Cheyenne River (Greene et al. 1990). Water movement above the Pierre Shale is shown in figure 3.5.

USGS groundwater retrieval of less than 100 feet shows water levels vary from about 6-70 feet in area wells. Most wells were last

Table 3.15: Characteristics of Groundwater in the Area

	Conductivity[1]	Arsenic (µg/L)	Zinc (µg/L)	Selenium (µg/L)	Nitrate NO3-N (mg/L)	Mercury (µg/L)	Depth of well (Feet)
Average	1980	0.9	75.5	1.6	0.6	0.2	120.8
Maximum	4940	11	1,157	12	1.6	0.76	940
Mininimum	300	0.5	4	0.2	0	0.1	19
EPA Standard	[2] 750	50	5,000	50	10	2,000	

[1] µ/mho/cm at 25 ºC.
[2] Converted from EPA's SMCL .
Source: EPA STORET Retrieval as of August 14, 1998.

measured in 1946 before irrigation in the District; a few were measured in the 1970s and 1980s (see Appendix U).

Quality

Table 3.15 summarizes results of 43 groundwater samples taken downstream of the dam in the District in Fall River and Custer counties. Most were collected in 1979, with a few collected from 1954-1995. Averages, maximums, and minimums of the samples are included the table, all of which were within EPA's drinking water standards (also included in the table). Appendix R details groundwater sampling (a location map is also available in Reclamation's Rapid City Field Office). USGS also collected samples from 19 wells in the Pierre Shale formation in 1988-1989. Average, maximum and minimum arsenic concentrations were found to be less than 1 µg/L (Greene et al. 1990). Average zinc concentration was 20 µg/L, maximum 57 µg/L, minimum less than 10 µg/L, while average, maximum, and minimum selenium concentrations were less than 1 µg/L. All of these are also within EPA's drinking water standards.

Little data is available on groundwater quality in the District, but the effects of irrigation on groundwater can be inferred. Greene et al. (1990) evaluated District groundwater by analyzing data from several aquifers within the Hot Springs topographic quadrangle. EC and an estimated TDS using a conversion factor of 0.7 (the approximate ratio of TDS:EC in the water of Fall River and Beaver Creek, both of which are heavily influenced by groundwater accretions) are shown in Table 3.16.

Based on surface water data from the District, Greene et al. concluded that groundwater quality in those aquifers was similar to that of the District (1990). Data from District wells (Table 3.16) indicate that groundwater quality is slightly better on average than that of the aquifers measured upstream, based on EC and estimated TDS (from the conversion mentioned above).

This analysis might indicate that wells in the District are drilled into different aquifers than those sampled by Greene et al.

Table 3.16: EC and TDS in District Groundwater

Location	EC (µmho/cm)	TDS (mg/L)
Alluvial Groundwater in Hot Springs Quadrangle	[1]2,380	[1]1,670
Shallow Bedrock Groundwater in Hot Springs Quadrangle	[1]2,180	[1]1,530
Groundwater under the District	[2]1,980	[2]1,390

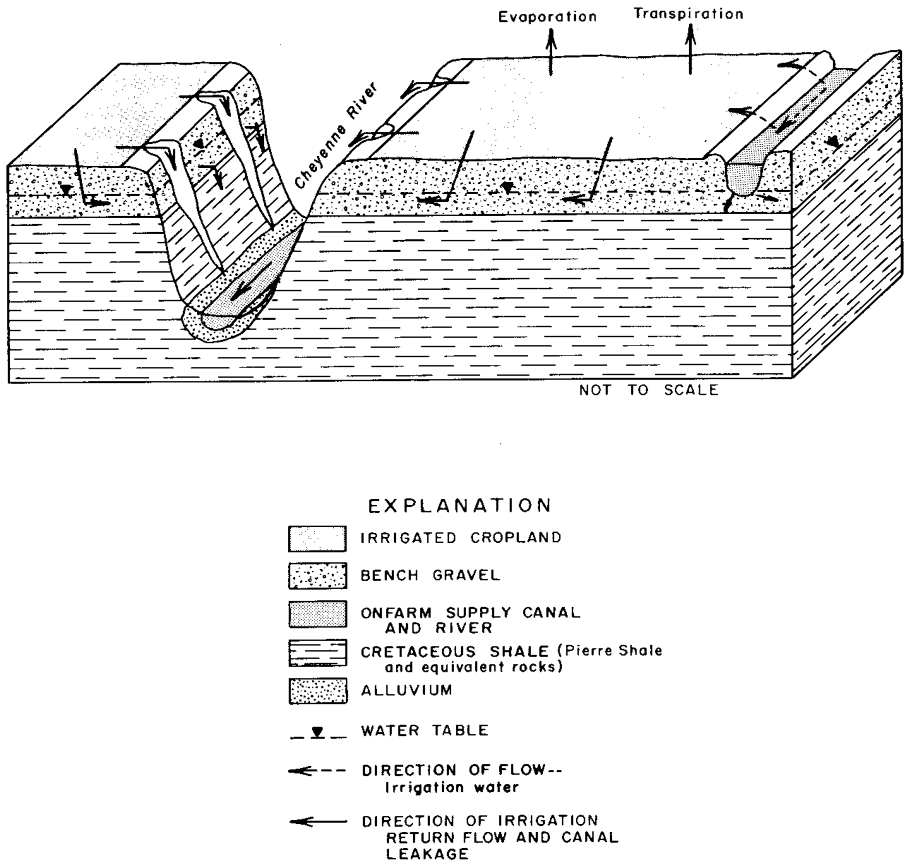
[1] Source: Greene et al. 1990.
[2] Source: EPA STORET Retrieval as of August 14, 1998.

SEDIMENT

Storage is lost in all reservoirs to the natural buildup of sediment transported by inflows, and Angostura Reservoir is no exception. Gradual loss of storage affects the water available for future uses. Concerns were also expressed by the public about the effect of sediment on water quality.

Quantity

The reservoir's original area-capacity relationship (see Table 3.3) was applied to Reclamation's DISSED computer model to predict future sedimentation in the reservoir. This model, developed to simulate sediment distribution in large reservoirs by the *Empirical*



Source: Greene et al., 1990.

Figure 3.5: Schematic of Irrigated Land in the District

Area Reduction method, follows the procedures outlined in *Reservoir Sedimentation Guideline* (U.S. Bureau of Reclamation 1962) and detailed in the *Revision of the Procedure to Compute Sediment Distribution in Large Reser-voirs* (U.S. Bureau of Reclamation 1982). Area capacities for 1997 and 2042 were predicted, with estimated sediment accumulation to con-tinue at 985 AF/year, much less than originally estimated. Total sediment for the 1949-2042 period was estimated to be 91,605 AF, indicat-ing a capacity loss of about 57%. Total capacity at elevation 3187.2 feet in 2042 would be 68,314 AF (the original capacity of 159,919 AF minus 2042 sediment of 91,605 AF), with active capacity of about 61,000 AF (2042 capacity of 68,314 AF minus inactive storage of 7,257 AF).

DISSED manual input and output data examples and a reservoir capacity/sediment distribution graph from the program are available from Reclamation's Rapid City Field Office (see Appendix I).

Quality

Studies by NIWQP, Reclamation, the OST, and CRST were used to analyze sediment quality in the reservoir and in the river downstream. The NIWQP database includes nine sites between USGS's Edgemont gauge and Red Shirt. Reclamation collected river sediment samples in August 1997 to update this database, resampled four of the NIWQP sites, and sampled three other NIWQP sites where water or aquatic species had been sampled but not the sediment. Locations and site numbers (assigned the NIWQP equivalent) were:

- 4a Angostura Reservoir Inflow Site
- 4b Angostura Reservoir Horsehead Creek Arm
- 4c Angostura Reservoir near the Dam
- 6 Angostura Canal
- 6S Angostura Canal split
- 9 Topeska's Pond
- 10 Iron Draw
- 11 Kimmie's Pond
- 12 Cheyenne River near Custer County Road 656 Bridge
- 14 Cheyenne River near Fairburn (Red Shirt)

Two additional sites—Cheyenne River at Rapid Creek (CRRC) and Cheyenne River at Cherry Creek (CRCC)—were sampled downstream from the NIWQP area to supplement the data and extend the area of study to near the confluence with the Missouri River.

No data is available for sediment in the tributaries to the Cheyenne or in return flows. Sediment from surface return flows would be similar to the area over which they flow, while groundwater return flows would contain very little sediment (see Appendix Q).

Bed sediment generally is derived from eroded soils. Samples of the sediment indicate constituents available for dissolution or re-suspension in water, as well as concentrations available to plants and animals. The NIWQP study compared bed sediment samples to conditions expected in western soils of the region (Shacklette and Boerngen 1984). The NIWQP study collected one sample from each of nine sites in 1988, and a sample from each of four sites in 1994. Reclamation collected bed-sediment samples at seven sites in 1997. The CRST began monitoring sediment in 1994: Samples from CRST sites near Cherry Creek were included in this analysis. Findings of these studies in comparison to a western soils baseline are shown in Table 3.17.

The NIWQP found selenium concentrations at the upper end of the baseline range. The maximum selenium concentration—at 10 times the upper end of the baseline—was from Cottonwood Creek near Buffalo Gap, an

Table 3.17: Characteristics of Sediment Quality in the Area (µg/L)

	Western Soils Baseline	NIWQP	Verification Study	Reclamation	CRST
Arsenic	1.2 - 22	6.2 - 15	<10 - 19	4.9 - 104.3	17 - 44
Barium	200 - 1,700	150 - 1,700	730 - 1,100	47 - 615	No data
Boron	5.8 - 91	1.2 - 7.3		4 - 27	No data
Cadmium		<2 - 2	<2 - <2	0.2 - 1.9	0.4 - 1.2
Chromium	8.5 - 200	20 - 85	6- 30	2 - 27	2 - 29
Copper	4.9 - 90	8 - 28	2 - 10	7 - 29	10 - 28
Lead	5.2 - 55	12-55	17-28	19 - <167	9 - 20
Manganese		220 - 1,800	23 - 610		333 - 2,640
Mercury	0.0085 - 0.25	<0.02 - 0.04		<0.1 - <0.1	<0.1 - <0.1
Molybdenum	0.18 - 4.0	<2-2	<2-<2	3 - 7.5	No data
Nickel	3.4 - 66	4 - 29	7 - 18	11 - 39	13.5 - 30
Selenium	0.039 - 1.4	0.6 - 14.0	<1 - <1	0.2 - 1.9	No data
Uranium	1.2 - 5.3	1.9 - 5.3	<100 - <100	2.5 - 17.8	No data
Vanadium	18 - 270	31 - 200	13 - 75	11 - 46	No data
Zinc	17 - 180	39 - 140	25 - 64	24 - 317	44.5 - 103

Source: Shacklette and Boerngen 1984.

unirrigated background site. This site also had the highest selenium concentration in water. Other results were all within the baseline range.

Bed-sediment concentrations from the Reclamation study were generally within the baseline range. One selenium concentration and several molybdenum concentrations were slightly above the baseline, however, and one zinc concentration was found nearly double the baseline maximum (Table 3.17). One arsenic concentration found at the Cheyenne River near Cherry Creek and the CRST study arsenic results were higher than baseline. This probably was due to effects of arsenic-contaminated sediment transported from Whitewood Creek.

STREAM CORRIDOR

Effects of the alternatives on the stream corridor along the Cheyenne River downstream of the dam was a major concern of the public. The stream corridor includes the stream channel itself and nearby riparian areas. Within the stream corridor, the channel and its flood plain are primarily formed and maintained through erosion, transport, and deposition of sediment by river flows (FISRWG 1998). Flows and sedimentation are therefore defining processes of stream corridors. Riparian areas exist at the joining of aquatic and upland ecosystems. For many western streams, riparian areas are a narrow band bordering the stream channel. Most riparian studies focus on plant communities. In this EIS, however, focus was the on the stream corridor, and, in addition to vegetation, on selected aspects of flows and sediment deposits. This approach was decided on because of the linkage between parts of the system: Flows, for example, dictate sediment transport, erosion, and deposition. Because riparian vegetation often is found on sediment deposits, changes in flows can also result in changes to vegetation, both directly and through changes in sediment deposits.

To understand how Angostura Dam affects the stream corridor, it is first necessary to understand how stream systems function. Meandering streams—such as the Cheyenne—have active channels that move within the flood plain by depositing sediment as point bars (on the inside of river curves, or *meanders*) and eroding the outside banks of meanders (Johnson 1992; Friedman et al. 1998). Point bars and other sediment deposits become seedbeds for future cottonwood and willow regeneration, while erosion often removes vegetation. As new vegetation establishes on a point bar, high flows may deposit more sediment and raise the bar's elevation. If sediment becomes high enough and vegetation large enough to withstand high flows, then it may continue to grow and mature until future channel meanders intersect, erode the site, and re-initiate the cycle. In unregulated western streams, erosion and deposition of sediments result in a diverse pattern of different-aged stands of riparian vegetation dominated by cottonwood and/or willows.

Stream channels function within a range of flows, sediment movement, and other factors dictated by conditions. If there are no large changes in flows and available sediment, the channel reaches a condition of balance—the volume of water and sediment entering the channel equal the water and sediment leaving the channel downstream, for example—a condition referred to as an equilibrium, or, because of natural variation, a *dynamic equilibrium* (FISRWG 1998). Changes in one or more of the channel factors, such as flows and/or available sediment, result in the stream adjusting to a new equilibrium supporting very different stream characteristics. Regulation by dams generally alters this pattern of seasonal flows by flattening periods of high flows and increasing flows during past periods (like winter) of low or no flows. The loss of high flows removes the dynamic process that would otherwise restructure the channel periodically and sustain different-aged plant communities.

Regulation also affects sediment supply. Given the idea of equilibrium, differences in some pre- and post-dam stream corridor characteristics should be expected, resulting from the channel adjusting to regulation-induced changes in flows and sediment.

The dam then affects flows, sedimentation, and the resources influenced by these processes within the river. Flows and sedimentation themselves affect many resources (a complete catalog of the relationship among flows, sediment, and other riparian resources is beyond the scope of this EIS—see Stanford et al., 1996; Poff et al., 1997; Johnson, 1998). For this EIS, analysis focused on a small number of indicators and measurement units believed to reflect changes in the stream corridor from changes in operation of the dam. These indicators are *selected channel characteristics* and *riparian vegetation*.

Selected Channel Characteristics

To better understand conditions in the stream corridor, selected Cheyenne River channel characteristics were examined as they currently exist and then compared to pre-dam conditions. It was assumed that differences between existing and pre-dam conditions would reflect how the river has adjusted to a new equilibrium. Aspects selected to represent channel characteristics include *flows*, *sediment*, and *length* of the stream.

Flows

As a first step in understanding how regulation has affected river resources, USGS stream gauge records were searched for flow information. While many gauges can be found along the river (see figure 3.1), only the Wasta gauge provided both pre- and post-dam flows. Post-dam data were divided into 15-year blocks corresponding to the 15 years of pre-dam data as shown in Table 3.18. The basic trends discussed would hold if the pre-dam data (15 years) were compared to the 45 years of post-dam data.

Data reflect a general reduction in annual flows at Wasta following construction of Angostura Dam. The increment attributable to the dam, however, cannot be determined. The drainage area represented at the Wasta gauge is about 12,800 square miles, while the drainage area at the dam is 9,100 square miles, the area at Edgemont 7,143 square miles (see Table 3.1). Also, Rapid Creek joins the river a few miles upstream from the Wasta gauge, which complicates interpretation. Rapid Creek flows were also being affected by Deerfield Dam (completed in 1947) and Pactola Dam (1956) during the post-Angostura Dam period of record at Wasta.

The matter is further complicated by the fact that the Cheyenne River is regulated not only by Angostura Dam and dams on the tributaries, but also by many private stock ponds and other impoundments in the basin (see "Surface Water Quantity" in this chapter). While the data indicate a general decrease in annual flows following dam construction, the exact cause probably results from a combination of factors. Thus, analysis of flows at Wasta provides only a general indication of how flows might have been altered by the dam. Data shown in Table 3.18 could have been affected in any of the 15-year periods by climatic events that increased or reduced flows.

In addition to lower annual flows, a change in seasonal flow patterns has also occurred. When the monthly data were combined into 3-month periods—winter (January, February, March), spring (April, May, June), summer (July, August, September), and fall (October, November, December)—patterns begin to appear as shown in Table 3.19. The largest reductions in flows have occurred in spring and summer, while flows have increased in the fall. If monthly data were selected that better fit the period of historic low flows (November-January) and compared to fall data (October-December), then the percentage increase over pre-dam flows is larger in all post-dam periods, except for 1980-1994. A similar adjustment to better fit historic high flows (May-July) indicates that a pattern of decreasing flows continues, as does the pattern for June (Table 3.19). June showed the greatest difference between pre- and post-dam flows.

Flow characteristics define the stream channel, as mentioned. Peak flows restructure the channel and provide bare areas of sediment suitable for establishment of new stands of cottonwoods and/or willows. A change in the frequency of peak flows would be expected to affect sediment deposit and riparian vegetation. Table 3.20 shows that frequency of channel-modifying flows above 5,000 cfs and above 10,000 cfs at Wasta have declined. The percent reduction is greater for intermediate flows (above 5,000 cfs) than for larger flows (above 10,000 cfs). The dam undoubtedly affects distribution and magnitude of peak flows, and some attenuation of all peak flows probably occurs as flows pass downstream and by the Wasta Gauge. Because of the limited storage at Angostura Reservoir, however, many of the larger peak flows probably pass through the reservoir unaltered.

Occurrence of peak flows, although reduced in frequency from pre-dam conditions, would provide some semblance of the river's historic dynamics (that is, exposed sediment—see

Table 3.18: Average Monthly Flow Computed from Data at the Wasta Gauge for Pre-Dam (1935-1949) and Post-Dam (1950-1994)

	Average 1935-1949		Average 1950-1964		Average 1965-1979		Average 1980-1994	
Jan.	74.11	4,556.56	82.71	5,085.88	96.36	5,925.16	103.81	6,383.05
Feb.	167.85	9,389.09	140.51	7,891.17	146.43	8,181.42	169.38	9,480.71
March	547.83	33,684.89	297.88	18,315.90	416.57	25,613.75	395.71	24,329.52
April	532.66	31,695.73	237.89	14,155.50	525.02	31,240.86	315.63	18,782.07
May	992.87	61,049.12	514.22	33,967.21	737.55	45,350.35	678.64	41,727.75
June	1,537.79	91,504.66	829.60	49,364.49	1,041.76	61,989.15	570.95	33,973.37
July	623.42	38,332.83	315.95	19,426.79	386.87	23,787.90	222.56	13,685.43
Aug.	214.41	13,183.74	159.78	9,824.32	181.80	11,178.58	130.97	8,051.65
Sept.	149.74	8,910.15	156.43	9,308.16	130.44	7,761.85	135.61	8,069.51
Oct.	113.26	6,963.83	103.57	6,368.53	141.97	8,729.52	177.21	10,896.51
Nov.	114.76	6,828.56	109.58	6,520.46	130.85	7,786.45	133.09	7,915.81
Dec.	79.99	4,918.61	98.16	6,037.55	105.05	6,458.97	104.71	6,438.07
Average Monthly	429.06	25,918.15	253.86	15,522.17	336.72	20,333.66	261.52	15,811.12
Average Annual AF		311,017.77		186,265.98		244,003.96		189,733.46

Table 3.19: Average Monthly Flows in the River, Pre- and Post-Dam

	Pre-Dam 1935-1949	Post-Dam 1950-1964		Post-Dam 1965-1979		Post-Dam 1980-1994	
	Average AF	Average AF	% Change from Pre-Dam	Average AF	% Change from Pre-Dam	Average AF	% Change from Pre-Dam
Winter (Jan.-March)	15,876.85	10,430.98	-34.3	13,240.11	-16.6	13,397.76	-15.6
Spring (April-June)	61,416.50	32,495.73	-47.1	46,193.45	-24.8	31,494.40	-48.7
Summer (July-Sept.)	20,142.24	12,853.09	-36.2	14,242.78	-29.3	9,935.53	-50.7
Fall (Oct. Dec.)	6,237.00	6,308.85	1.1	7,658.31	22.8	8,416.80	34.9
Historic Low Flows	5,434.58	5,881.30	8.2	6,723.53	23.7	6,912.31	27.2
Historic High Flows	63,628.87	34,252.83	-46.2	43,709.13	-31.3	29,795.52	-53.2
June	91,504.66	49,364.49	-46.1	61,989.15	-32.3	33,973.37	-62.9

Table 3.20: Number of Flows Greater than 5,000 cfs and 10,000 cfs at Wasta, Pre-Dam and Post-Dam

Period	Number of Flows >5,000 cfs	Number of Flows >10,000 cfs
1935-1949	58	14
1950-1964	28	8
1965-1979	37	12
1980-1994	19	7

below). These changes in river dynamics are likely linked to expansion of water impoundments (Angostura Reservoir, tributary reservoirs, and many smaller livestock impoundments), direct surface diversion, groundwater pumping, and channel alteration.

Sediment

In addition to reduced flows, the Cheyenne River has probably experienced a reduction in volume of sediment transported through the stream corridor. For example, about 29,151 AF of sediment was trapped by the reservoir from 1949-1979 (see "Sediment: Quantity" in this chapter). This sediment is no longer available for transport downstream, so releases, seepage, or spills from the reservoir are relatively sediment-free.

Length

Channel balance is maintained between the stream's energy (interaction of flows and slope) and size and volume of sediment moved (FISRWG 1998). If, for instance, the volume of sediment entering the stream corridor were reduced—perhaps trapped behind a dam—then the channel would probably adjust through flattening its slope, if all other variables remained constant. However, all variables do not remain constant, so prediction of channel adjustment presents a challenge. For purposes of this EIS, present conditions can be measured, compared to pre-dam conditions, and used to explain the channel's response.

Channel length over a given distance can be used as an indirect measure of channel slope. Basically, the flatter the slope, the more sinuous the channel; conversely, the steeper the slope, the straighter the channel. The river channel was measured on 1991 aerial photos in 25-mile increments for 200 miles downstream of the dam. Channel length was then measured to the same downstream point on 1948 aerial photos. The results showed that channel length increased from about 185 miles in 1948 to 200 miles in 1991, a 7.5% increase (U.S. Bureau of Reclamation 1998). It appears the channel slope of the Cheyenne River has flattened in response to reduced flow and available sediment. This results from a combination of factors, including construction of the dam.

Riparian Vegetation

Unregulated western rivers often experience high spring snow-melt flows and occasional intense summer rainfall, often high enough to restructure sediment deposits and erode vegetation established since previous high flows. Dynamic flows ensure that sediment and vegetation are constantly changing.

Regulation can affect many channel characteristics and associated riparian vegetation. To understand existing riparian vegetation conditions, selected reaches of the Cheyenne River were examined as they are now, and then compared to pre-dam conditions. High quality black-and-white aerial photographs of the river from October-November 1948 were used to represent pre-dam conditions, while July-August 1991 photographs represented post-dam conditions at present. Figure 3.6 is a GIS presentation based on aerial photos of the Red Shirt area for the two periods.

It was assumed that differences between present and pre-dam conditions reflect how riparian vegetation has responded to regulation of the river. Aspects selected included the area (acres) of *exposed sediment* within the channel, *area coverage* (acres) of riparian vegetation, number of *vegetated polygons* (or patches) within the flood plain, and area (acres) of change in various classes of vegetation *canopy closure*.

Various means to measure riparian vegetation can be used to show how the stream corridor has changed. Reduced flows, for example—especially reduced peak flows—have probably permitted vegetation to establish on exposed sediment deposits. Areas of exposed sediment deposits would thus be expected to decline and areas of vegetation to increase following dam construction. Vegetation (cottonwood and willow) establishment on exposed sediment would also result in more vegetated polygons within the stream corridor.

Finally, canopy closure, or the percentage of ground surface hidden by foliage in aerial photographs, was used as a gross estimate of age. It was assumed, for instance, that polygons supporting dense cover (81-100% closure) are young recently established cottonwood and willow, while polygons supporting open cover (1-20% closure) are mature stands.

Exposed Sediment

Areas of exposed sediment (non-vegetated in-channel sediment deposits) were determined from river photographs for a length of 200 miles below the dam under similar flows in 1948 and 1991. (Sediment could result from high flows occurring 1-2 years before the photos were taken.) Areas of exposed sediments declined from 13,784 acres in 1948 to 7,156 acres in 1991, a decline of 48% (U.S. Bureau of Reclamation 1998). Table 3.21 shows the acres of exposed sediment.

Table 3.21: Exposed Sediment and Vegetation Coverage, and Total by 25-River Mile Increments below Angostura Dam (Acres)

Miles Below Dam	1948			1991		
	Exposed Sediment	Vegetation Coverage	Total Area	Exposed Sediment	Vegetation Coverage	Total Area
1-25	717	420	1,137	319	800	1,119
26-50	1,103	2,010	3,113	429	2,226	2,655
51-75	1,173	2,512	3,685	693	2,745	3,438
76-100	1,437	2,698	4,135	878	2,892	3,770
101-125	1,670	2,814	4,484	990	2,894	3,884
126-150	1,856	3,153	5,009	1,129	3,847	4,976
151-175	3,163	2,689	5,852	1,458	4,316	5,774
176-200	2,665	1,734	4,399	1,260	3,277	4,537
Totals	13,784	18,030	31,814	7,156	22,997	30,153

Dakotas Area Office GIS

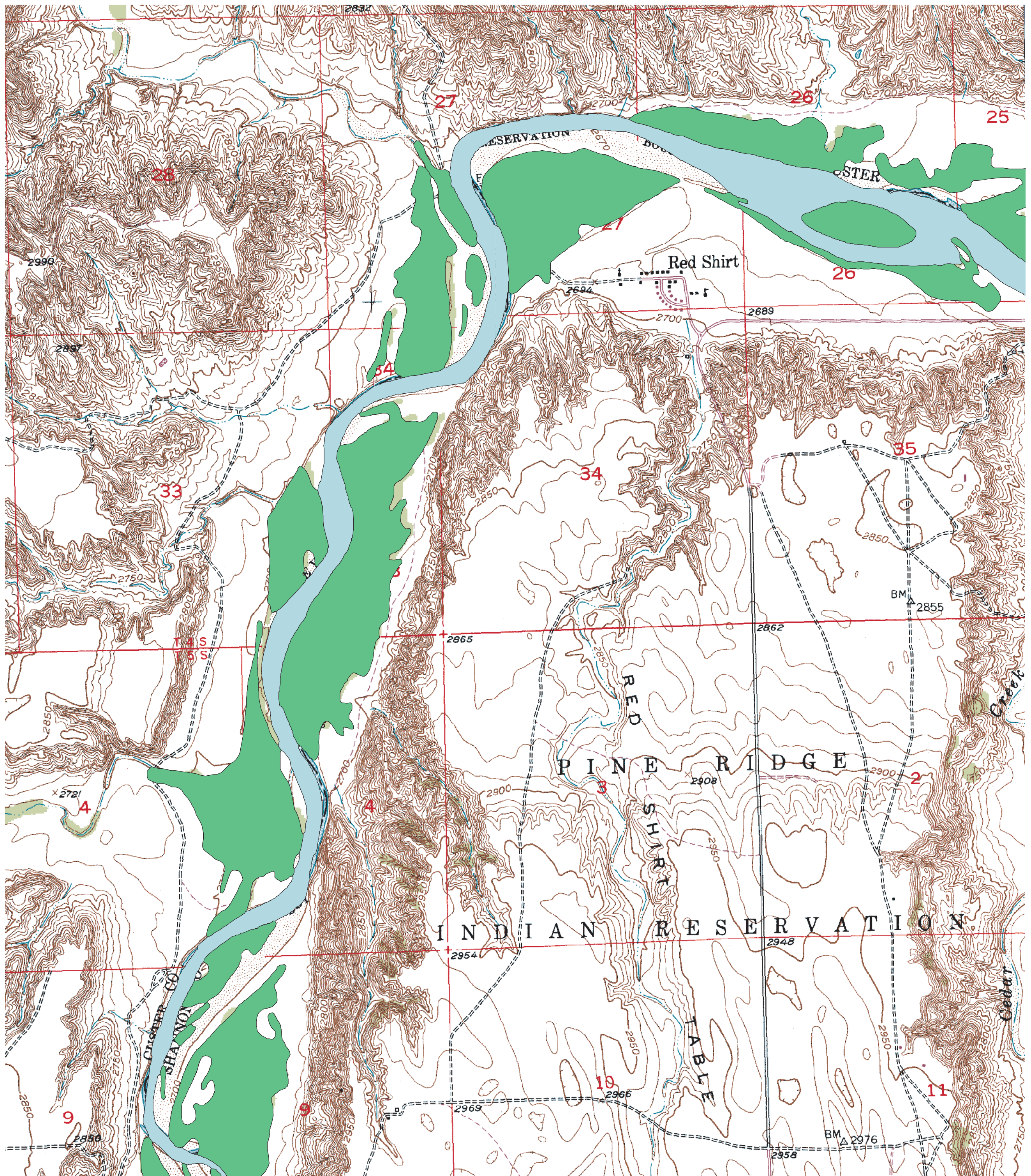
Fig. 3.6

ANGOSTURA UNIT BELOW DAM

RIPARIAN HABITAT AND RIVER CHANNEL CONFIGURATION CHANGES

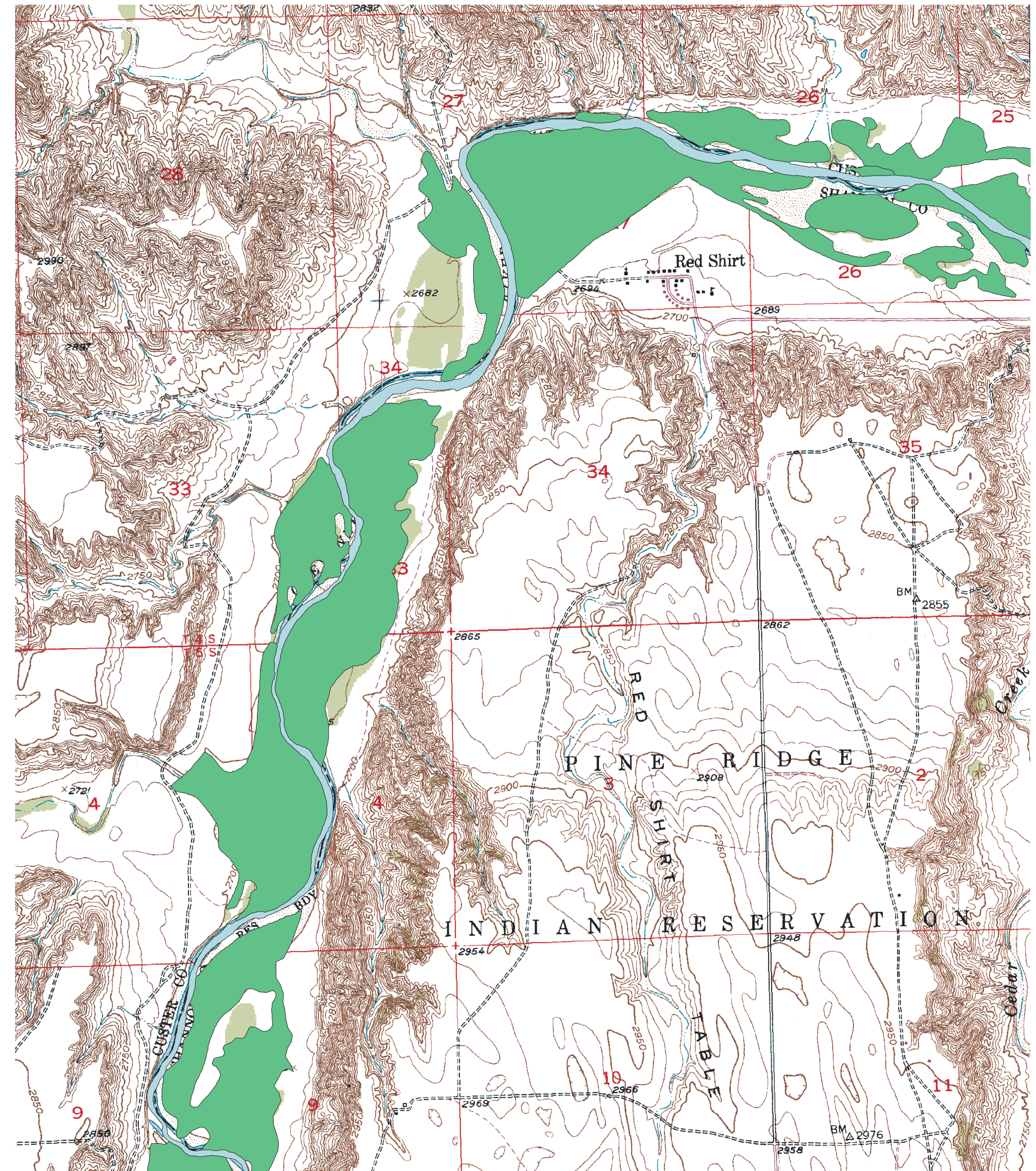
LEGEND
- RIVER
- VEGETATION

1948 PRE DAM CONDITONS



SUM OF VEGETATIVE ACREAGE
1948 AREA DISPLAYED = 678.5 ACRES
1948 TOTAL ACREAGE = 3265.3 ACRES

1991 POST DAM CONDITONS



SUM OF VEGETATIVE ACREAGE
1991 AREA DISPLAYED = 790.9 ACRES
1991 TOTAL ACREAGE = 3870.3 ACRES

0 0.5 1 1.5 2
MILES

Date: 14-SEP-2000
e:/data/angostura/dendata/angst/vegdata/map48-91

Area Coverage

Areas of riparian vegetation within the flood plain were also determined from photographs for a length of the river 200 miles below the dam under similar flows in 1948 and 1991 (figure 3.6). Areas of riparian vegetation increased from 18,030 acres in 1948 to 22,997 acres in 1991 (as shown in Table 3.21), an increase of 27.5% (U.S. Bureau of Reclamation 1998).

Decreases in exposed sediment and increases in riparian vegetation are probably linked. For purposes of analysis, the 200 miles below the dam was divided into 25-mile increments. Changes over time in these increments were noted, including total changes in areas of sediment and vegetation. This process allowed the conclusions in Table 3.21 to be drawn. In general, while areas of exposed sediment declined and areas of vegetation increased from 1948-1991, the total combined area in sediment and vegetation remained similar.

Vegetated Polygons

The number of vegetated polygons within the flood plain was determined from river photographs for 200 miles below the dam under similar flow conditions in 1948 and 1991. This number increased from 841 in 1948 to 1,113 in 1991, an increase of 32% (U.S. Bureau of Reclamation 1998). If vegetation has increased through occupation of exposed sediment as postulated above, then the number of vegetated polygons would increase as indicated by these data.

Percent Canopy Closure

The dominant woody plant found in the riparian zone is cottonwood. Small isolated bands of willows have established immediately next to the banks of the river in some areas. Many of the stands are mature trees with open canopies (see "Wildlife" in this chapter).

Canopy closure was evaluated from photographs of the area to better understand riparian vegetation response to stream regulation. Vegetated polygons within the floodplain for 200 miles downstream of the dam were categorized by canopy closure as shown in Table 3.22. Sparsely vegetated (1-20% canopy closure) polygons were the most numerous category in photographs for both 1948 (15,126 acres) and 1991 (15,898 acres); this category increased by approximately 770 acres between 1948-1991. While all categories showed increases in area coverage, the 21-40% canopy closure category experienced the largest increase in area coverage. Although further study is needed, it is postulated that this category represents a large part of the trees that occupied exposed sediment deposits following construction of dam.

Table 3.22: Canopy Closure and Area of Riparian Vegetation below the Dam (Acres)

Canopy Cover (%)	1948	1991
1-20	15,126	15,898
21-40	2,783	6,199
41-60	110	765
61-80	11	123
81-100	0	12
Totals	18,030	22,997

WETLANDS

Wetlands—dominated by persistent emergent vegetation, emergent mosses or lichens, trees, and shrubs—constitute important wildlife habitat in the Angostura Area. Also, concerns were expressed by the public about wetlands.

While their number and acreage in the area are not great, wetlands add greatly to wildlife use and species diversity. A variety of waterfowl, upland game birds, songbirds, shorebirds and neo-tropical migrants use this habitat. Wetlands in the area have been grouped according to location, function, and type. These groups are:

- Those in the reservoir
- Wetlands surrounding the reservoir
- Wetlands in the District
- Riparian or riverine wetlands.

National Wetlands Inventory maps were used to determine acreages in each category as shown on figure 3.7.

Angostura Reservoir is a manmade, deep water wetland with 4,612 acres of surface area at elevation 3187.2 feet. It provides some shallow-marsh habitat along the shore, primarily at the upper end. Wetlands also occur in uplands surrounding the reservoir. Natural depressions or small manmade impoundments, these wetlands rely on precipitation for their existence. About 376 acres of wetland can be found around the reservoir.

About 794 acres of wetlands are in the District along the river. These wetlands are greatly influenced by return flows through surface run-off and groundwater. Riparian or riverine wet-lands occur along the Cheyenne River and with-in the flood plain. They are influenced by the river in one or more ways, being cut-off river meanders or oxbows, depressions that fill when the river floods, or river-influenced springs or fens. About 2,085 acres of riparian or riverine wetlands occur along the river. Of that total, the river makes up 1,617 of these acres, with 468 acres of wetlands proximate to the river.

FISHERIES

Concerns were expressed by the public about effects of the alternatives on reservoir and river fisheries in general, with particular concern by the OST directed to fish health.

The Cheyenne River is a large warm water stream with variable flows, sandy substrate, and high turbidity and dissolved solids. Everman and Cox (1896) investigated the Cheyenne River in 1892-1893 to report on suitable sites for fish hatcheries in the region. They described the river as "ordinarily a shallow stream whose waters are always more or less alkaline and filled with solid matter in suspension from the extremely easily eroded country through which it flows " (p. 336).

Fisheries in the Angostura area can be divided into three distinct river segments:

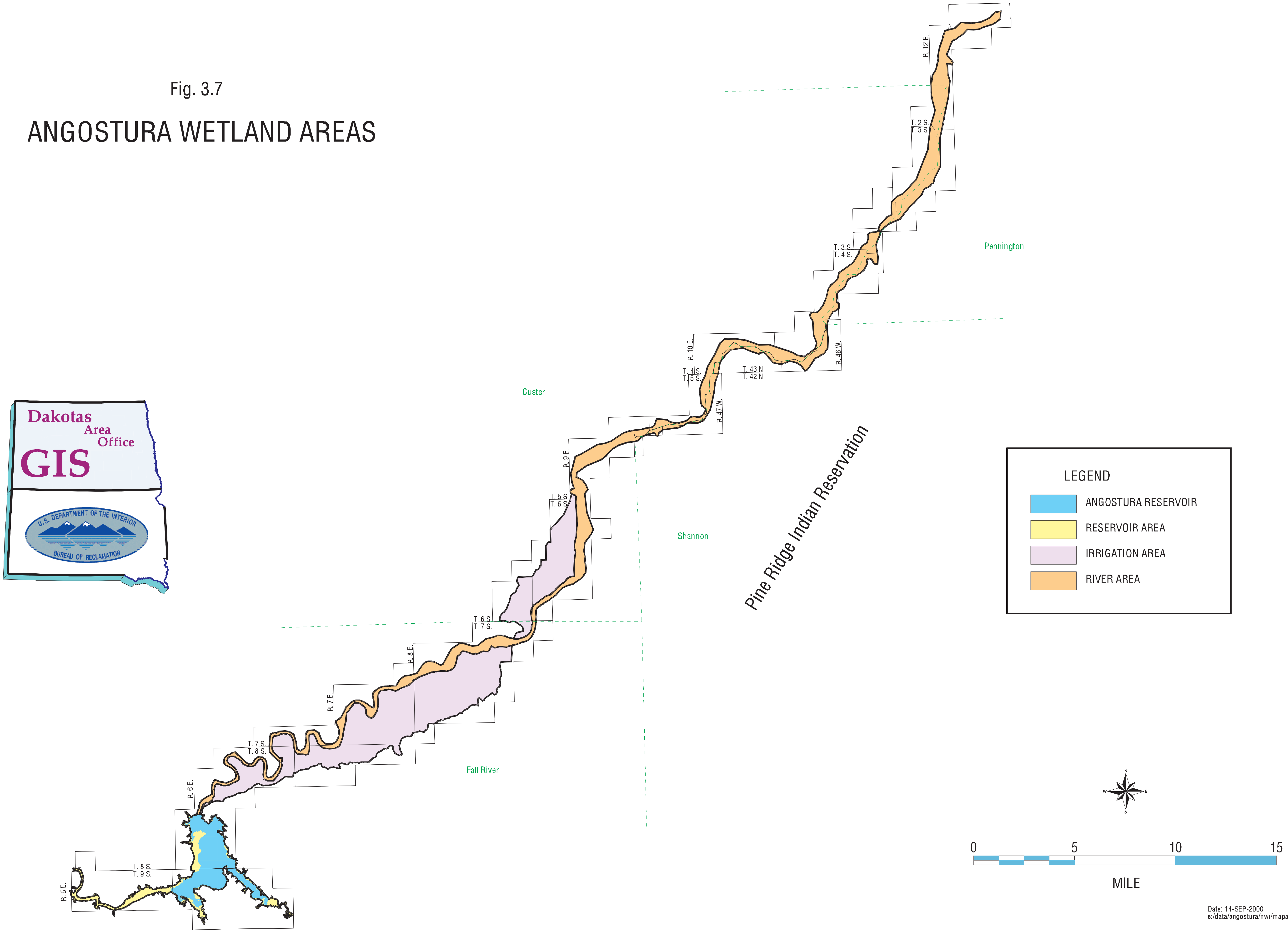
- Angostura Reservoir and upstream (upper Cheyenne River)
- The river from below the dam to its confluence with the Belle Fourche River (middle Cheyenne River)
- The river from its confluence with the Belle Fourche to Lake Oahe (lower Cheyenne River).

Angostura Reservoir

Angostura Reservoir at elevation 3187.2 feet extends about 17 miles up the Cheyenne River and 7.6 miles up Horsehead Creek. The reservoir has 4,612 surface-acres at this elevation. Water elevations fluctuate greatly from month to month and year to year, depending on inflows and irrigation releases. Fluctuating water elevations prevent extensive development of aquatic vegetation, essential for fish spawning, as well as escape cover for larval fish. SDGF&P (South Dakota Game Fish and Parks Department) believe the fluctuating water elevations are responsible for the low reproductive success of gamefish and forage species at the reservoir (Lee Vanderbush 1998: personal communication). While not extensive, some aquatic vegetation has developed in the inlets and shallows on the west side of the

Fig. 3.7

ANGOSTURA WETLAND AREAS



reservoir. Emergent vegetation includes cattails, willows, and smartweed, while submergent vegetation is primarily coontail and elodea.

SDGF&P instituted a fish stocking program because of low reproductive success. In recent years, walleyes and largemouth bass have been stocked. Emerald shiner and gizzard shad have also been introduced to supplement the forage base for game fish. Table 3.23 lists species found in the reservoir, while Attachment 1 at the end of the EIS lists year, species, and approximate numbers stocked in the reservoir since construction.

Table 3.23: Fish Species in the Reservoir

Common Name	Scientific Name
Walleye	***Stizostedion vitreum vitreum***
Largemouth bass	***Microptirus salmoides***
Emerald shiner	***Notropis atherinoides***
White sucker	***Catostomus commersoni***
Bluegill	***Lepomis macrochirus***
Gizzard shad	***Dorosoma cepedianum***
Smallmouth bass	***Microptirus dolomieui***
Channel catfish	***Ictalurus punctatus***
Black bullhead	***Ictalurus melas***
Yellow perch	***Perca flavescens***
Common carp	***Cyprinus carpio***
Northern pike	***Esox lucius***
Black crappie	***Pomoxis nigramaculatus***
Spottail shiner	***Notropis hudsonius***
Rockbass	***Ambloplites rupestris***
Green sunfish	***Lepomis cyanellus***
Northern redhorse	***Moxostoma aureolum***
River carpsucker	***Carpiodes carpio***
Fathead minnow	***Pimephales promelas***

Middle Cheyenne River

The river from below Angostura Dam to the confluence with the Belle Fourche River is typical of western streams after regulation and introduction of exotic fish species. Water is colder here than water downstream and less turbid since the reservoir acts as a settling basin. The stream bears considerable energy and erosive power. Reduced releases to the river since the dam was built—coupled with small contributions from tributaries—has resulted in a segment of the river that does not consistently flood to any great degree. The river channel thus shifts very little, with reaches that have eroded down to bedrock.

The fishery in this segment has also exhibited changes. Fish species requiring turbid water are found less frequently or not at all, having been replaced by fish species (many of them introduced exotics) preferring clear, less turbid water.

Lower Cheyenne River

As the Cheyenne River flows towards Lake Oahe, turbidity and water temperature increase due to erosion, clay soils, a low stream gradient, and influence of large tributaries like the Belle Fourche River. This segment supports fish communities more tolerant of turbid warm-water conditions. The furthest downstream reaches are affected by Lake Oahe and its fish community.

Table 3.24 lists fish species identified in the middle and lower Cheyenne River, demonstrating change in species composition in the last 100 years. Surveys by Everman and Cox (1896); Churchill and Over (1933); and Bailey and Allum (1962) collectively documented 15 species of fish in the Cheyenne River (Hampton 1998). Surveys conducted by Hampton (1998) documented an additional 16 species.

Table 3.24: Fish Species in the Cheyenne River Between the Dam and Lake Oahe

Common Name	Scientific Name
Documented in Early Studies (Bailey and Allum 1962)	
Flathead chub	***Platygobio gracilis***
Plains minnow	***Hybognathus placitus***
Sand shiner	***Notropis stramineus***
Channel catfish	***Ictalurus punctatus***
Shorthead redhorse	***Moxostoma macrolepidotum***
River carpsucker	***Carpiodes carpio***
Stonecat	***Noturus flavus***
Sturgeon chub	***Macrhybopsis gelida***
White sucker	***Catostomus commersoni***
Longnose dace	***Rhinichthys cataractae***
Fathead minnow	***Pimephales promelas***
Plains killifish	***Fundulus zebribus***
Black bullhead	***Ictalurus melas***
Green sunfish	***Lepomis cyanellus***
Orangespotted sunfish	***Lepomis humilis***
Documented by Hampton (1998) But Not Previously Recorded	
Western silvery minnow	***Hybognathus argyritis***
Emerald shiner	***Notropis atherinoides***
Goldeye	***Hiodon alosoides***
Red shiner	***Cyprinella lutrensis***
White bass	***Morone chrysops***
Freshwater drum	***Aplodinotus grunniens***
Smallmouth bass	***Micropterus dolomieui***
Sauger	***Stizostedion canadense***
Spottail shiner	***Notropis hudsonius***
Plains topminnow	***Fundulus sciadicus***
Largemouth bass	***Micropterus salmoides***
Common carp	***Cyprinus carpio***
Creek chub	***Semotilus atromaculatus***
Yellow bullhead	***Ameiurus natalis***
Bluegill	***Lepomis macrochirus***
Northern pike	***Esox lucius***

Fish Health

The OST are concerned that fish are being affected by the Angostura Unit. Tribal members said they have seen fish in the river with lesions or open sores, and that populations may not be as abundant as they were in the past. In response, Reclamation, in cooperation with the OST, SDGF&P, USGS, South Dakota State University, and the USFWS (U.S. Fish and Wildlife Service), collected 101 fish from three sites in the river in August 1997, September 1998, and November 1998. The three sites were ¾ mile below the dam, at Oral, and at Red Shirt/Fairburn. Species collected were: Channel catfish, goldeye, white sucker, and shorthead redhorse. The samples were sorted and packaged in the field and sent frozen to NLS (Northern Lake Services) Crandon, Wisconsin, for tissue analysis.

This reduced-scale sampling was a followup to the NIWQP sampling and analysis done in 1988 (Greene et al. 1990), and was meant to supplement the NIWQP's 1994 Verification Study. Samples were analyzed for eight trace elements and a variety of organic contaminants, including herbicides, insecticides, and several PCB (polychlorinated biphenyl) isomers. The NLS results were then compared to the NIWQP study. The 85 percentile of the USFWS' NCBP (National Contaminants Bio-monitoring Program) provided the baseline, as shown in Table 3.25. Tissue of a total of 67 fish were sampled for heavy metals including aluminum, arsenic, beryllium, copper, mercury, selenium, thallium, and zinc.

Table 3.25: Baseline for Fish Tissue Analysis (mg/kg wet weight [milligrams per kilogram])

	NCBP Geometric Mean[1]	NCBP 85th Percentile	NCBP 85th Percentile	Other Levels	
		[1]1990	[2]1985	Level Used	Source
Aluminum				[3]100	4-100 (Animals in general)
Arsenic	0.16	0.24	0.23		
Beryllium				[3]0.6	.05-.6 (Animals in general)
Copper	0.72	1.00	1.02		
Mercury	0.11	0.17	0.18		
Selenium	0.45	0.71	0.18		
Thallium				[3]0.10 [4]0.19	(Animals in general; Fish in Minimata Bay[5])
Zinc	22.3	40.2	43.23		

[1] Schmitt and Brumbaugh 1990. Average of samples collected in 1978-1979, 1980-1981, and 1984.

[2] Lowe et al. 1985. Used in the NIWQP report; average of 1978-1979 and 1980-1981 samples.

[3] Pais and Jones 1997.

[4] Smith and Carson 1977.

[5] Contaminated site in Japan.

At the Oral site, samples were above baseline concentrations for copper, selenium, and zinc. Selenium was most frequently observed above its baseline concentration (over 80%). Copper and zinc were above the baseline in over 50% of the samples. The frequency of exceeding the background at the Red Shirt site for each of the trace elements exceeding baseline at Oral was much lower. Only half the percentage of copper and selenium samples at Red Shirt exceeded the baseline in comparison to the Oral site, while no zinc samples were greater than baseline at the Red Shirt site. Trace element concentrations were higher above the District than below.

The NLS noted the samples were contaminated with zinc during preparation. The absence of

Table 3.26: Contaminant Concentrations in Fish (In mg/kg)

	EPA Fish Advisory Screening Value	Below Dam 1998	At Oral 1997	Fairburn/Red Shirt 1998	Fairburn/Red Shirt 1997
Aluminum	None		21.055		11.834
Arsenic	1.35	<0.25	<0.26	<0.25	<0.27
Beryllium	None		<0.034		<0.039
Copper	none	1.916	1.163	1.145	1.014
Mercury	0.45	<0.075	<0.024	<0.075	<0.023
Selenium	22.5	<0.720	<1.030	<0.387	<0.678
Thallium	None		<0.44		<0.43
Zinc	None	11.039	22.73	11.72	18.54

Source: EPA 1999.

results greater than the baseline at Red Shirt site indicate zinc contamination did not significantly affect the samples at the downstream site.

Analytical recovery of mercury spikes in 1998 by NLS was low, ranging from 44-65%. Only 3 of 67 samples had measurable mercury, and all of these were less than 0.1 mg/Kg (milligram/kilogram), the reporting limit. NLS in 1999, however, improved recovery to more than 90%.

Significant differences in trace element concentrations were found among the fish species sampled. White suckers were significantly higher in aluminum, copper, and selenium than the goldeyes or channel catfish, while channel catfish were significantly lower in zinc than the other species.

Channel catfish showed a significant decrease in concentrations of aluminum, selenium, and zinc, and a significant increase in the copper concentration between the 1988 and 1997 samples. Goldeyes showed only a significant decrease in zinc. Changes in aluminum, copper, and selenium may be specific to a particular species, but the decrease in zinc was shown for all species, and thus could be true of river fish in general. A total of 34 fish were sampled for organic chemicals by Greene et al. (1990). The analytes included 20 insecticides, 14 herbicides, and 7 PCB's. Of these, seven insecticides and one herbicide were found in measurable concentrations in the fish (no PCB's were found). Six of the seven insecticides are now banned, so these apparently represent residue from past use. All were persistent organochlorines. The remaining insecticide, *methoxychlor*, is not known to be used on District lands. The herbicide observed in fish samples, *alachlor*, is used in the District, but the residue in tissue is lower downstream of the District than upstream. Fish exhibited lower tissue residues of organochlorines than has been shown in a representative sample of fish from other streams in the United States.

Table 3.26 shows heavy metals concentrations found in fish during the 1997-1998 sampling of the river compared to EPA's *Fish Advisory Screening Values* (EPA 1999). Arsenic, mercury, and selenium had screening values. Concentrations of the three metals were well below corresponding screening values as shown in the table.

No fish with lesions or open sores were observed during the 1997-1998 sampling. The OST Water Resources Department consulted with SDGF&P to determine the origin of lesions and sores seen earlier. In an appendix to the OST Report (Appendix Y in this EIS), Rick Cordes, Fish Health Specialist for SDGF&P, stated:

> The small raised ulcers, 3-5 mm [millimeters] in diameter, some hemorrhagic, were the attachment sites of small leeches, Myzobdella moorei, in the family, Piscolidae. These leeches were observed, September 26th, attached to the fins on the catfish sampled. The leeches on the body were most likely causing irritation and were simply dislodged from the catfish by rubbing their skin on the river bottom substrate. The leeches observed on the fins are more difficult to dislodge. Bacterial infections at the sites where leeches were attached are causing the lesions. The bacteria isolated from the kidney and liver are fairly common and may damage internal organs if water quality is poor or the fish cannot cope with the number of leeches attached and the associated secondary bacterial infections. The leeches are opportunistic parasites and maybe more numerous in the Redshirt [sic] area because of the discharge from the water treatment plant. The bacteria are easily killed in properly cooked fish and are usually nonpathogenic to humans. I do not believe that the lesions observed are the result of contaminants entering the river. (11)

Analysis indicates there may be low DO at times in the river near Red Shirt (see Table 3.10). Causes of the low DO have not been determined, but an OST consultant suggested wastewater discharge from the Red Shirt water treatment plant (Hoof 1998, Appendix 5, p. 2). In fish already stressed from leeches and associated infections, the added stress of low DO could cause further fish health concerns or fish mortality.

Details of the fish tissue analysis can be found Appendix Q.

WILDLIFE

Comments from the public were received about effects of the alternatives on wildlife and wildlife habitat.

The Angostura area is relatively diverse in habitat and thus in wildlife species, located as it is in the transition zone between ponderosa pine woodlands of the Black Hills and mixed-grass prairie of the Northern Plains (see Attachments 2 and 3 for Angostura-area plant and wildlife species, respectively). Irrigated District croplands within juniper uplands and mixed-grass prairie lie next to the Cheyenne River downstream of the dam. Riparian habitat—more diverse in plant and animal species than surrounding habitat—provides an important connection between aquatic and upland habitat.

Analysis of wildlife impacts focused on prairie woodlands (cottonwoods) and associated bird species for several reasons:

- Prairie woodlands habitat is the main area influenced by regulation of river flows
- Other wildlife species like small and large mammals are not as affected by regulation of flows as are bird species
- Data are readily available for the northern Great Plains and can be applied to the Cheyenne River.

Prairie woodlands contribute to bio-diversity of the semiarid grasslands of the northern Great Plains. Prairie woodlands are riparian or riparian-like habitat (Boldt et al. 1978; Uresk and Boldt 1986) restricted to areas of more moisture, such as north-facing slopes or drainages (Girard et al. 1989). Prairie woodlands provide habitat for many bird species on the northern Great Plains (Emmerich and Vohs 1982; Faanes 1984; Sieg 1991). Greater density of vegetation and layering of the vegetative understory, typical of prairie woodlands, increases species richness and density of passerine birds (Willson 1974; Roth 1976; Rotenberry and Weins, 1980). Mature woodlands are essential to sustaining populations of some bird species in the northern Great Plains.

For this analysis, changes in woodland types from cottonwood to green ash or grassland/ shrub and changes in bird species diversity were used as indicators of effects from changes in river flows.

Cottonwoods

Cottonwood riparian woodlands are important to bio-diversity. Generally declining along major rivers in the plains region, these woodlands will probably decrease in abundance and distribution in the future, while green ash woodlands increase (Johnson et al. 1976; Johnson 1992). Many cottonwood sites in a study on the Missouri River showed green ash in the understory (if undisturbed) eventually dominating the woodland community (Mark Rumble 1998: personal communication). Most cottonwood riparian woodlands in this study consisted of mature trees. The flooding necessary for regeneration of cottonwood riparian woodlands restricts early seral stages (young trees) to narrow bands next to the Missouri River and its tributaries.

Along the Cheyenne River, cottonwoods (*Populas deltoides*) live for about 100-150 years. Currently, cottonwood riaprian woodlands in the area are a mixture of late seral and late-intermediate seral (old trees), with a grass/shrub understory. These trees are about 50-60 years old, established by field transects by Reclamation, the OST, and USFS (U.S. Forest Service) using the USFS' draft *Cottonwood Model* to determine age classification. Transects were also run above Angostura, where cottonwoods were found to be the same age as those below the reservoir.

Grazing occurs throughout the area, managed by Federal agencies (Reclamation controls grazing on lands surrounding the reservoir) and by private land owners. Livestock use cottonwood riparian woodlands for forage and shade and to avoid flies (Uresk 1982; Bjusstad and Girard 1984). In many cases, livestock have destroyed the understory, leading to degradation and loss of this habitat type (Severson and Boldt 1977). Degradation of woodlands from livestock use also reduces bird abundance (Hodorff et al. 1988).

Bird Species

Bird species found in the cottonwood woodlands in the Angostura area were classified as tree, cavity, shrub, and ground nesters for this analysis (Table 3.27). These species are highly

Table 3.27: Bird Species in Old Age Cottonwoods in the Area

Cavity Nesting Birds	Tree Nesting Birds	Shrub Nesting Birds	Ground Nesting Birds
Downy woodpecker	Mourning dove	Brown thrasher	Common yellowthroat
Red-headed woodpecker	Western kingbird	Bell's vireo	Vesper sparrow
Northern flicker	Eastern kingbird	Yellow warbler	Lark sparrow
Black-capped chickadee	Blue jay	Indigo bunting	
House wren	American robin	Rufous-sided towhee	
	Warbling vireo		
	Blackheaded grosbeak		
	Common grackle		
	Orchard oriole		
	Northern oriole		
	American goldfinch		

Source: Mark Rumble 1998: personal communication.

dependent on late seral stage prairie woodlands. Because birds differ in environmental requirements, their populations can be used as an indicator of environmental conditions in the area (Martin and Finch 1995). Presence of bird species associated with riparian woodlands, for instance, indicates the composition and structure of these woodlands (Mosconi and Hutto 1982). Other wildlife, such as small and large mammals, are less dependent on riparian woodlands in comparison to passerine birds (Faanes 1984; Sieg 1991).

THREATENED OR ENDANGERED SPECIES

This section of the EIS introduces the biological assessment required under Section 7c of the Endangered Species Act. The assessment's purpose is to:

1. Assure that compliance with the act is incorporated into early planning decisions and alternative selection

2. Establish and promote interagency cooperation and consultation in project decisionmaking which may affect listed and candidate species

3. Develop possible conservation and mitigation measures to avoid or reduce identified impacts.

The USFWS (as required under the act) provided a list of endangered, threatened, and candidate species that are or may be present in the area from the reservoir to the confluence of the Belle Fourche and Cheyenne Rivers (Table 3.28). Information for the table came from Ashton and Dowd (1991). The SDGF&P provided a list of species of special status (Table 3.28), which included eight species on the USFWS list. Protection of rare species in the area is also undertaken by the South Dakota Natural Heritage Program, a cooperative project of The Nature Conservancy and SDGF&P. This program documents and monitors the rarity

Table 3.28: Endangered or Threatened Species and Species of Special Status

Species	Scientific Name	Federal Status	State Status
Bald Eagle	***Heliaeetus leucocephalus***	Threatened	Endangered
Whooping Crane	***Grus americana***	Endangered	Endangered
Piping Plover	***Charadrius melodus***	Threatened	Threatened
Interior Least Tern	***Sterna antillarum athalassos***	Endangered	Endangered
Black-footed Ferret	***Mustela nigripes***	Endangered	Endangered
Mountain Plover	***Charadrius montanus***	Proposed	
American Burying Beetle	***Nicrophorus americanus***	Endangered	Endangered
Swift Fox	***Vulpes velox***	Candidate	Threatened
Black-tailed Prairie Dog	***Cynomys ludovcianus***	Candidate	Pest
Sicklefin Chub	***Hybopsis meeki***	Candidate	Threatened
Sturgeon Chub	***Hybopsis gelida***	Candidate	Threatened
Plains Topminnow	***Fundulus sciadicus***		Threatened
Finescale Dace	***Phoxinus neogaeus***		Endangered
American Peregrine Falcon	***Falco peregrinus anatum***		Endangered
Fringe-tailed Myotis	***Myotis thysanodes pahasapensis***		Rare
Marten	***Martes americana***		Rare
Black Bear	***Ursus americanus***		Rare
Mountain Lion	***Felis concolor***		Rare
Long-nose Sucker	***Catostomus catostomus***		Threatened
Banded Killifish	***Fundulus diaphanus***		Endangered
Osprey	***Pandion haliaetus***		Threatened
Baird's Sparrow	***Ammodramus bairdii***		Rare
Spiny Softshell	***Apalone spinifera***		Threatened
Short-horned Lizard	***Phrynosomoa douglasi***		Rare
Regal Fritillary	***Speyeria idalia***		Rare
Ottoe Skipper	***Hesperia ottoe***		Rare
Great Blue Heron	***Ardea herodias***		Rare
Common Merganser	***Mergus mergnaser***		Rare
Golden Eagle	***Aquilla chrysaetos***		Rare
Barn Owl	***Tyto alba***		Rare

Table 3.28: Endangered or Threatened Species and Species of Special Status (Continued)

Species	Scientific Name	Federal Status	State Status
Burrowing Owl	***Speotyto cunicularia***		Rare
Brewer's Sparrow	***Spizella breweri***		Rare
Quillback	***Carpiodes cyprinus***		Rare
Plains Spotted Skink	***Spilogale putorius interrupta***		Rare
Tiger Beetle	***Amblychila cylindriformis***		Rare
Lareflower Townsend Daisy	***Townsendia grandiflora***		Rare
Bitter Fleabane	***Erigeron acris***		Rare
Barr's Milkvetch	***Astragalus barii***		Rare
Lewis Woodpecker	***Melanerpes lewis***		Rare

and possible threat to continued survival of about 400 species, as well as a number of unique natural features and plant communities.

Bald Eagle

The bald eagle was reclassified from endangered to threatened in the lower 48 States in 1995, and it has recently been proposed for de-listing. South Dakota lists them as endangered. By restricting DDT, increased protection, and reintroduction, breeding pairs have increased dramatically over the years. Eagles may pass through any part of the State during migration, and they winter near open water where large trees provide roosting sites. A single active nest was reported along the Missouri River below Fort Randall in 1990, the first confirmed successful bald eagle nest in South Dakota since 1885. This same nest also was successful in 1991.

Nesting activity and success have increased recently. The USFWS in 1998 documented 14 active nests in the State, all but one located along the Missouri River between Fort Randall and Sioux City, along the James River in eastern South Dakota, and near Sisseton in the northeast corner of the State. Other nests have been reported east of the Missouri but have not been confirmed. The only confirmed active nest west of the Missouri is on the Belle Fourche River at the Meade-Butte County border. This nest was active 1997-1999. Two other nests were reported in the Black Hills but have not been confirmed (Jay Peterson 1999: personal communication).

Although wintering eagles depend primarily on fish, they are opportunistic feeders and their diet varies by region. Thus, rabbits and waterfowl, as well as carrion, are also taken. Wintering eagles are associated with unfrozen lake, river, and wetland habitat. Distribution depends on prey density, suitable perch and roost sites, weather conditions, and freedom from human disturbance. Their numbers normally fluctuate at particular wintering areas. Dams have caused changes in winter bald eagle distribution, concentrating populations by providing forage places below the dams. The presence of a fishery, however, does not necessarily mean eagles will be attracted to the area.

Whooping Crane

The whooping crane has been listed as endangered by both USFWS and SDGF&P. Most sightings occur in April-May and September-October and are within a north-south corridor 100 miles east and 150 miles west of Pierre. The Angostura area is within the migration corridor used by the Wood Buffalo-Aransas population. Single cranes, cranes in pairs, family groups, and small flocks use areas in South Dakota as nontraditional stopover sites on the annual migration. Suitable sites include cropland and pastures, wet meadows, shallow marshes, shallow parts of rivers and reservoirs, and alkaline basins. Sites are used opportunistically, usually for short periods like overnight or for several days if inclement weather is encountered (Armbruster 1990). Habitat characteristics vary but usually include shallow water, gently sloping shoreline, and no human activity.

Cranes are relatively long-lived, reaching 22-24 years in the wild. Breeding may begin at age three, but more typically at four. Although two eggs are typically laid, rarely do both survive to fledge. Cranes are opportunistic feeders during migration, readily exploiting any suitable plant or animal food item they encounter, including cultivated grains like barley, corn, sorghum, and wheat (Armbruster 1990). Feeding occurs in both uplands and wetlands.

Piping Plover

The piping plover was listed in 1985 as threatened by USFWS in all of its range outside the Great Lakes (where it's listed as endangered). It is listed as threatened by SDGF&P. Reproductive success is generally low, and successful breeding pairs usually fledge only one chick. Plover numbers declined over much of their range as a result of habitat destruction, unstable water levels, and human disturbance of nesting adults and chicks. Rising water levels are a major cause of nest and chick losses. There is one nesting record for Angostura Reservoir (Nell McPhillips 1997: personal communication). Plovers occur in the State as late spring and early summer residents, generally from late April-August.

Nests are located on sparsely vegetated islands, sandbars, and shorelines on the higher parts of beaches away from the waterline and vegetation. Nests—shallow, scraped depressions, sometimes lined with small pebbles, shells, or other debris—frequently are found in association with least tern nests (*Federal Register* 1985). The female plover lays four eggs after which both parents share in incubation lasting about 28 days. Chicks leave the nest shortly after hatching but continue to be tended by both parents for about 30 days until they are able to fly (U.S. Fish and Wildlife Service 1988). Until they fledge, young remain within 400-500 feet of the nest (Johnsgard 1979). Fledging is usually completed by mid-late August.

Food habits are not well known (Corn and Armbruster 1993). Small invertebrates such as terrestrial worms, crustaceans, mollusks, and insects found at or near the water's edge are taken as food (U.S. Fish and Wildlife Service 1988).

Interior Least Tern

The interior least tern was listed by USFWS as endangered through most of its past range in 1985 (it is also listed as endangered by SDGF&P). The breeding population has been reduced to a remnant due to human disturbance during nesting (U.S. Fish and Wildlife Service 1988) and habitat degradation from the effect of dams, channeling, and diversion on river flows. Parts of the Missouri River in South Dakota, Nebraska, and Missouri have lost 99% of the nesting sites available at the turn of the century (*Federal Register* 1985). The only areas where the tern is still known to breed are on sand bars along the Cheyenne River, around Lake Oahe, and along the Missouri River in the southeast part of the South Dakota.

Nests are generally found on flat, open sand or pebble beaches within or very close to the flood plain of large rivers, lakes, and reservoirs. Nests are usually barren except for scattered clumps of vegetation, and are often next to shallow pools, riffles, and river backwaters offering abundant small fish populations (U.S. Fish and Wildlife Service 1988). Breeding colonies usually are comprised by up to 20 nests spaced far apart (Johnsgard 1979; *Federal Register* 1985). Terns frequently are found in conjunction with piping plovers (U.S. Fish and Wildlife Service 1988). Females lay 1-4 eggs, and both parents incubate (U.S. Fish and Wildlife Service 1988).

The tern feeds almost exclusively on small fish, but they have also been known to eat crustaceans and insects. They will travel up to 2 miles from their nest sites in search of food (U.S. Bureau of Reclamation 1988).

Black-footed Ferret

The black-footed ferret was listed in 1964 as endangered by USFWS and is similarly listed by SDGF&P. A mink-sized member of the weasel family, the ferret measures 18 inches long and weighs 2.5 pounds. It has a black mask, black feet, and a black-tipped tail, with back and sides of tan or yellow, an underside of white or cream. Although never abundant, their range once extended across nearly 100 million acres in 12 States and 2 Canadian provinces (Clark 1989). The ferret became endangered following destruction of habitat and prey-base by poisoning prairie dogs over the past 70 years (Clark 1989). The last confirmed sighting of a black-footed ferret in South Dakota was in Fall River County in 1983.

The nocturnal secretive ferrets are most often seen in late summer and early fall. Tracks are practically identical to those of mink, but ferrets dig a long, narrow furrow or trench section directly out of a prairie dog burrow. Besides characteristic trenching, ferrets also show their presence by burrows which prairie dogs are suspected to plug as a defense. Ferret habitat includes open grassland, steppe, and shrub steppe areas. They are almost always associated with prairie dogs, living in prairie dog towns, raising their 2-5 young in prairie dog dens, and preying almost exclusively on the rodents. They have also been known to take mice, rats, ground squirrels, rabbits, and various birds, reptiles, and insects (Fagerstone 1987).

The ferret was thought to be extinct until a wild population was discovered near Meeteetse, Wyoming, in 1981. During 1985-1987, the remaining 18 black-footed ferrets of this population were captured (*Federal Register* 1993). By 1993, the population of ferrets had increased to 300 and was divided into 7 captive populations (*Federal Register* 1993). They were released in Shirley Basin/Medicine Bow, Wyoming, in 1991, and in the Charles M. Russell National Wildlife Refuge, Montana, and in South Dakota in 1994.

Ferrets have been released at Badlands National Park and Buffalo Gap National Grasslands, with a goal of establishing 100 breeding animals (Doug Albertson 1999: personal communication), which would sustain the local population. A total of 328 ferrets has been released to date at the two sites, with another release planned for 1999. Surveys in March 1999 counted 22 ferrets in Badlands National Park and 125 ferrets in the Buffalo Gap National Grasslands. Two naturally reproduced litters were observed in 1995, five in 1996, five in 1997, and 24 litters in 1998. It is anticipated that the 1999 survey will show that the 100-breeding ferret goal has been met.

Mountain Plover

The USFWS proposes to list the mountain plover as a threatened species (*Federal Register* 1999). At the turn of the century, declining numbers were attributed to market hunting. Hunting of the birds was abolished in 1916, but numbers continue to fall due to conversion of prairie to agricultural land, range management practices leaving vegetation too tall, urban sprawl (primarily on wintering grounds), and the continued extermination of prairie dogs. Plovers are also vulnerable to human and vehicular disturbance during courtship, nesting, and brood rearing. Adults have been known to abandon eggs when disturbed. Pesticide use may also pose a threat through direct toxicity to mountain plovers or by reducing food supplies.

The plover is a bird of shortgrass prairie and shrub-steppe landscapes both for breeding and wintering. Breeding occurs in the Rocky Mountain States and Canada south to Mexico, with most breeding birds found in Montana and Colorado. Most wintering birds can be found on grasslands or similar landscapes in California, with fewer birds wintering in Arizona, Texas, and Mexico. The plover is thought to be eliminated from South Dakota.

The plover evolved on grasslands inhabited by large numbers of nomadic grazing ungulates—bison, elk, and pronghorn—and burrowing mammals—kangaroo rats, badgers, and prairie dogs. Herbivores dominated the prairie landscape, and their grazing, wallowing, and burrowing maintained a mosaic of vegetation and bare ground to which the plover became adapted. Unlike other plovers, mountain plovers are rarely found near water. Short vegetation, bare ground, and flat topography are recognized as habitat-defining characteristics for both breeding and wintering locales (*Federal Register* 1999).

In many areas, mountain plovers are closely associated with prairie dog towns, but tilled fields also serve as habitat. Use of fields almost assures breeding failure, as nests are destroyed by farming operations or abandoned once crops become too tall.

Plovers arrive on the breeding grounds by late March. The nest is a simple scrape on the ground lined with organic debris, typically with area vegetation less than 4 inches high, at least 30% bare ground, and with a conspicuous object such as a cow chip, clump of vegetation, or a rock nearby (Knopf and Miller 1994). Taller vegetation in the area to shade chicks and adult birds is also necessary. Nest sites occur on ground with less than 5% slope. They usually lay three well-camouflaged eggs. Only one adult attends the nest during the 29-day incubation period. Some evidence suggests a female produces one clutch of eggs for her mate to attend, and then produces a second clutch about 2 weeks later which she attends herself. The brown-speckled chicks reach adult size 35 days after hatching. Flocks of plovers begin to form as early as mid-June and increase in size until mid-August. Migration occurs between August and October.

Plovers feed primarily on insects. The type of prey changes throughout the season as one type of insect or another becomes more prevalent. The mountain plover can thrive without drinking freestanding water as it obtains sufficient water from its food.

American Burying Beetle

The American burying beetle (also known as the giant carrion beetle) was listed by USFWS as endangered in 1989 and is similarly listed by SDGF&P. The beetle, up to 1.4 inches long, was once widely distributed throughout North America, having been reported in 32 States and 3 Canadian provinces (Houtcooper et al. 1985; USFWS 1988; *Federal Register* 1989). There are records of the beetles in Gregory and Tripp counties in eastern South Dakota, and recent surveys found them in Haakon and Bennett counties. For reasons unknown, however, the beetle is no longer found throughout most of its original range.

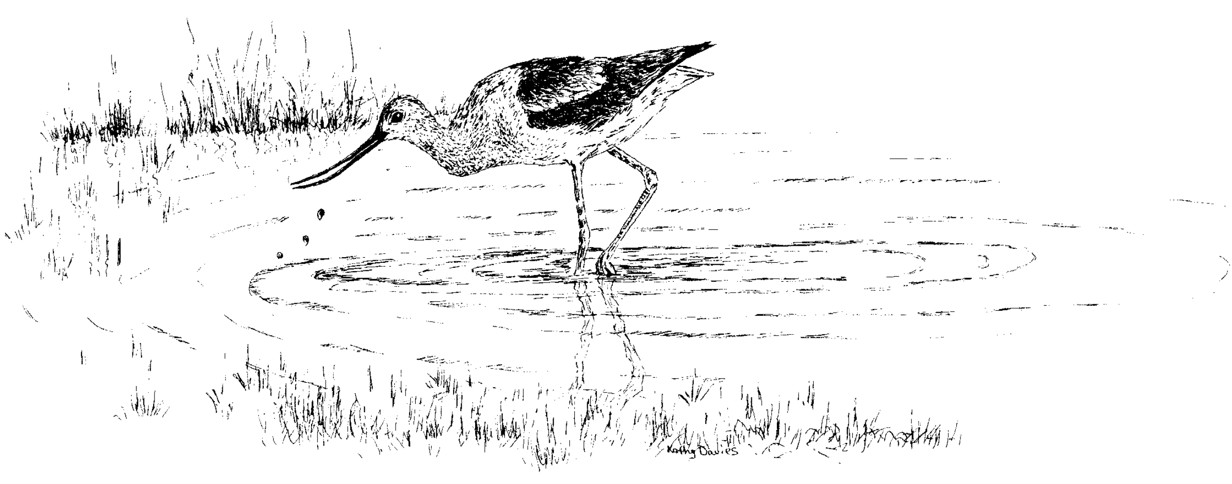
Habitat has not been clearly defined. Although virgin or primary forest has been suggested as preferred habitat, several beetles captured in the Midwest after 1960 were in mixed agricultural lands—including pastures and mowed fields—and ordinary second-growth woods. Current distribution, as outlined by captured beetles, suggests it can also occur in grasslands habitat.

While beetles have been seen consuming live insects (U.S. Fish and Wildlife Service 1988), generally they locate a dead animal, excavate underneath, and then bury the carcass. The buried carcass serves as food for the beetles' larvae. Coated with secretions that slow decomposition, the carcass is essentially preserved in a semi-mummified state (White 1983). The female lays eggs in an adjoining tunnel. Larvae are fed regurgitated pabulum until they are ready to pupate (Milne and Milne 1980). Occasionally, two broods of young are produced, but the young do not reproduce until the following June or July. Adults are believed to overwinter singly in the soil (*Federal Register* 1989).

Swift Fox

The swift fox is listed by USFWS as a candidate species, while SDGF&P lists it as threatened, noting that occurrence is "critically rare" and that its habitat continues to be seriously threatened (Houtcooper et al. 1985). It is 27-34 inches long and weighs about 4-6 pounds, about the size of a large house cat. Pale buff with a white underside, the fox has characteristic large triangular ears, dark spots on the muzzle below the eyes, and a black-tipped, bushy tail.

The fox was once abundant on the North American prairie from Canada to the Texas Panhandle (*Federal Register* 1995). It was found throughout South Dakota. By 1900, however, the fox was eliminated from the northern parts of its range (Scott-Brown et al. 1987). No sightings were reported in the State



from 1914-1966 (Scott-Brown et al. 1987), although there have been sightings since then. Based on current distribution, the USFWS estimates the fox is gone from 80-90% of its past range. Remaining populations are found in scattered, isolated pockets of remnant short-mid grass prairie habitat. Loss of prairie to agriculture and mining, recurring drought in the Midwest, and prairie dog control have reduced habitat and prey for the fox. It is also easily trapped and readily takes poison bait intended for coyotes and red fox (*Federal Register* 1995).

The fox now appears to be well established in eastern Colorado, western Kansas, eastern New Mexico, and eastern Wyoming. Smaller populations can be found in western Nebraska, southwest South Dakota, and the Texas Panhandle. It has been reintroduced in Canada, where a captive breeding program has met with success.

Unlike coyotes and other foxes, the swift fox uses dens year round. It may excavate its den near hilltops, in a sandy stream valley, along a fence row, roadside ditches, level pastures, and—when favorable sites are not available—in cultivated fields (Scott-Brown et al. 1987). They may also occupy abandoned badger dens or prairie dog burrows. The fox breeds in early spring, producing 4-5 pups (ranging from 1-8) 51 days later. Pups emerge from the den in a month and are weaned at 6-7 weeks. Parents may move the pups several times. The pups disperse from the den during late summer. Normally a nocturnal hunter, the fox is an opportunistic predator, feeding on small mammals, birds, insects, reptiles, vegetation, and carrion.

Black-tailed Prairie Dog

The black-tailed prairie dog was listed by USFWS as a candidate species in 1999, while the State lists it as a pest. Black-tailed prairie dogs are stout, burrowing animals, about 14-17 inches long and weighing about 1-3 pounds. They are generally yellowish in color, slightly lighter on the belly, with short ears and a short black-tipped tail. Conversion of prairie to farmland in the eastern part of their range between 1890-1930, repeated poisonings from 1920-1970, and sylvatic plague (which results in near 100% mortality in a colony) has reduced the number of black-tailed prairie dogs and the size and number of colonies.

Black-tailed prairie dogs were one of the most conspicuous and characteristic residents of the short- and mixed-grass prairies of the United States. It is estimated that they once numbered 5,000,000,000, occupying over 100,000,000 acres. Today, black-tailed prairie dogs occupy about 1,000,000 acres within their original range. While complexes of more than 10,000 acres still exist, most colonies are small— typically less than 100 acres—disjunct, and geographically isolated from the others. They occupy between 150,000-250,000 acres in South Dakota, with a stable to expanding population. Four of the seven relatively large complexes (greater than 10,000 acres each) remaining in North America are in the State. Black-tailed prairie dogs occupy one colony of about 50 acres in the Angostura area, just west of the dam.

Within the colonies, black-tailed prairie dogs live in contiguous, territorial family units called *coteries*. Female black-tailed prairie dogs do not breed until their second year and usually live 3-5 years. They produce a single litter annually, usually of 4-5 pups. Migration is limited to about 3 miles. Black-tailed prairie dogs dispersing from their home colonies usually move into other established colonies rather than attempting to start a new colony.

Sicklefin Chub

The sicklefin chub is also listed by USFWS as a candidate species. The SDGF&P lists it as threatened, noting that it is "critically rare in the State and that its habitat has been greatly reduced by main stem impoundments" (Houtcooper et al. 1985). The chub grows to a maximum length of 4 inches. It is extremely rare throughout much of its range, habitat having been destroyed by dams and canals. It is adapted to large, turbid rivers with strong currents over a bottom of sand or fine gravel (Pflieger 1975). In South Dakota, the chub has only been known to occur in the Missouri. Suitable habitat also can be found in the Cheyenne River.

Young chub have been collected from the Missouri in July, suggesting a spring spawning season. It is believed to be a bottom-feeder (Pflieger 1975).

Sturgeon Chub

The sturgeon chub is also listed by USFWS as candidate species. The SDGF&P lists it as threatened, noting that it is "critically rare in the State and. . . its habitat is rare and seriously threatened" (Houtcooper et al. 1985). The fish are mottled olive green-brown on back and have a silvery-cream underside, with characteristic small *keels* or ridges of skin on each scale of their upper body. Keels are believed to help the chub maintain position in fast currents. These keels identify the chub from the very similar longnose dace. Reaching a maximum of 4 inches long, chub have small eyes and a long fleshy snout overhanging the mouth. Dense concentrations of tiny external taste buds can be found on the lower head, body, and fins.

The chub originally could be found in the Missouri River drainage from Montana to the confluence with the Mississippi River and from the Mississippi drainage to the mouth of the Ohio River. In South Dakota, the chub has been found in the Missouri, White, Grand, Little Missouri, and Cheyenne Rivers. It remains extremely rare throughout most of its range, though, its habitat having been destroyed by dams and channelization (Pflieger 1975).

The chub is well equipped for life in continuously turbid water (Pflieger 1975) over sand or gravel areas where the current is swift (Brown 1971; Pflieger 1975).

The oldest recorded sturgeon chub was 4 years old; less than 5%, however, live 3 years. It matures its second year. Spawning occurs in the spring and early summer at water temperatures of 65-72 ºF. Fish ready to spawn (ripe) have been collected from early June until the end of July. About 15-20% of a ripe female's body weight is composed of eggs. No detailed studies have been done on feeding, but chub are believed to be bottom-feeders. Stomachs of collected fish have contained unidentified insect parts. The chub may be preyed upon by walleye, sauger, pike, and burbot.

SOCIAL AND ECONOMIC CONDITIONS

Comments from the public focused on social and economic effects of the alternatives on irrigators, the counties, the State, Pine Ridge Reservation, and the region. The Angostura Unit generates income and employment by expenditures for crop production, farm income, and recreation-related goods and services, directly affecting economic conditions in the area. Changes in water management could indirectly affect communities and lifestyles in the area, so a social analysis was done based on the regional economic analysis, focusing on changes in agriculture and recreation brought on by changes in operation of the reservoir.

After a discussion of methods, this section is made up of two parts: The first covers population characteristics and the economy of Fall River and Custer counties. These counties contain most (if not all) of the Angostura Unit and the District, and most of the effects would be felt in this area. Since the Reservation is distinct from the counties in both population characteristics and economy, it has been accorded a section of its own. The town of Red Shirt, lying along the river on the northwest boundary of the Reservation, is the area the OST believes is most affected by the Angostura Unit. Social and economic conditions on the Cheyenne River or Lower Brule Reservations would not be affected, so they were not included in the analysis.

Methods

Regional Economic Analysis

Regional economic impacts were measured using the IMPLAN computer model, which translates changes in final demand for goods and services (such as agriculture and recreation expenditures) into resulting changes in the value of total output of the region, changes in employment, and changes in income. The coefficients used to represent purchases within the region were adjusted to reflect greater than average purchases of corn and hay from the local region, which translated into greater local impacts from any change in crop production.

Regional impact analysis accounts for *direct*, *indirect*, and *induced* impacts of spending. Direct impacts are linkage between an economic activity and spending required by that activity: Fertilizer, seed, labor, machinery, and other inputs needed, for example, to produce 100 bushels of corn. Purchasing the inputs generates direct impacts. Indirect impacts result from demands necessary to supply the inputs. Induced impacts are the result of income generated by direct and indirect impacts that are spent in the region. Some of the income earned by a person providing agricultural or recreational services spent at the OST's casino represents an induced economic impact of agricultural and recreational activity on the Reservation.

Another important factor in the economic analysis was the effect of reduced water deliveries on crop production. If water were conserved by changing applications or by the timing of applications, crop yields might be maintained with less water. If water were not available, however, at critical times during the growing season—or if even minor volumes of water were unavailable—then reduction in crop yields might be significantly greater than the reduction in water deliveries.

A final consideration was the change in cropping patterns occurring from uncertain water deliveries. A change in availability of water to the District could result in significant changes in crops and economic activity. Local producers said that delivery of 75% of full irrigation would lead many to switch to dryland small grains, milo, and sudan grass forage (Jerry Watt 1998: personal communication). Small grains might be economically viable on the better lands, although pasture would be the most likely viable dryland crop in the region after several years of establishment.

Local producers indicated that drought in the short term would result in reduced cultivated acreage roughly proportional to reduced water availability. This would be caused by reducing irrigated acreage to allow near full water deliveries to the remaining acres. It would be very difficult to replace irrigated crops on short notice because of the timing of planting, length of the growing season, and timing of harvest.

Over time, acreages that could not be irrigated would probably be taken out of production and put into pasture or possibly small grains. This would result in reduced agricultural activity, reduced agricultural income, and reduced spending in agricultural input sectors. Regional economic impacts of reduced irrigated acreage therefore were based on value of crop production and cost of production inputs per acre of irrigated land, minus crop value and input costs per acre of dryland, multiplying the difference by the reduced irrigated acreage.

Recreation Analysis

A computer model based on reservoir elevations and reservoir visitation was developed to estimate recreation impacts. Monthly reservoir elevations were obtained from Reclamation records, and annual visitation information for 1970-1996 was provided by SDGF&P's Division of Parks and Recreation. Economic data on changes in per capita income were collected for April-September, assumed to be the recreational season in the area. Average seasonal precipitation was included in the regression equation to account for the effects of weather on camping visitation.

The regression equation used in the analysis was represented as change in camping visits = f (change in the seasonal average reservoir elevation, change in seasonal precipitation, and a change in per capita income). Many other variables were considered, but data were either lacking or insufficient to explain changes in camping visitation. Independent variables (reservoir elevation, precipitation, and per capita income) were found to be significant based on the t and F statistics, and the expected signs for the variables were correct. The adjusted *R-square* is a statistical measure indicating how well the independent variables explain changes to the dependent variable (camping visitation). The regression equation developed for this analysis has a low adjusted R-square (.35), but this is probably due to the absence of other independent variables which influence camping visitation. Still, it was found that changes in reservoir elevations were statistically significant and would play a role in camping visitation at the reservoir.

Once the regression model was developed, seasonal average reservoir elevations for each alternative were obtained from AGRAOP. Using these data—and assuming other independent variables constant in the model—changes in camping visitation for each alternative were estimated. It was recognized that much recreation at the reservoir comes from day-use. Past visitation data showed that, on average, there were 10 day-use visits to each camping visit. This ratio was multiplied by the change in camping visitation to estimate change in day-use visitation.

Changes in reservoir elevations affect recreation facilities. Table 3.29 shows target elevations established in the alternatives and the recreational purpose they would serve. The model didn't take into account qualitative impacts to boat ramps or other aspects such as beaches or the shoreline. Visitation is down when boat ramps are inaccessible because of low water. On the other hand, when the reservoir is full, beaches are inundated and shoreline day-use may be reduced. Qualitative impacts to facilities and beaches can be assessed, however, by comparing when boat ramps would be inaccessible at various reservoir elevations. The table was developed using the same parameters as for the AGRAOP model based on the average of 10,000 irrigated acres.

County Population Characteristics

The 2000 population of the area was 14,728 (Table 3.30). Approximately 51% of this population resided in Fall River County, the rest in Custer County. Custer County's population grew at an annual average rate of less than 1% from 1980-1990, increasing to 1.7% from 1990-2000. Fall River County's population declined from 1980-1990 by about 13%, or 1.2% as an annual average rate. Population projections from the State Data Center at the University of South Dakota estimate the Fall River County population to continue to decline between 1995-2010, perhaps due to a further decline in agriculture and lack of industry in the county. For Custer County, population is projected to increase between 2000-2010 at about 1% annually.

Table 3.29: Recreation Elevations in the Reservoir (Assuming 10,000 irrigated acres)

Elevation (Feet)	Recreational Benefit	% of 1953-1997 Period Elevations Achieved
3187.2	Target elevation December-May—most favorable for fish	11 months or 4.1%
3186	Target elevation in June—most favorable for fish and for beach formation	23 months or 51.1%
3185	Target elevation in July—most favorable for fish and for beach formation	12 months or 26.7%
3184	Target elevation in August-November—most favorable for fish and for beach formation	31 months or 17.2%
3175	All eight boat ramps at reservoir usable for April-September	220 months or 81.5%
3173	Elevation at which water conservation measures would be taken in Reservoir Recreation and Fisheries Alternative to preserve recreational benefits for April-September	238 months or 88.2%
3172	Four boat ramps usable for April-September	244 months or 90.4%
3170	Two boat ramps usable for April-September	252 months or 93.3%
3163	Top of inactive pool—no boat ramps usable	270 months or 100%

The largest town in Fall River County is Hot Springs with 3,891 people, which comprised more than 50% of the county's 2000 population (U.S. Department of Commerce 1990; 1997; 1999). In Custer County, the largest town is Custer with 1,853 people, comprising 25% of the county's 2000 population. Population trends for the towns follow patterns described for total county populations. Custer County's population increased in most towns between 1990-1999, while the towns in Fall River County declined during the same period. By way of comparison, Rapid City, the major regional center about 50 miles north of the reservoir, increased by about 6% during the same period.

About 94% of the population was white in the 2000 Census in Custer County (U.S. Department of Commerce 2000). Native Americans made up about 3.1% of the population, with other races making up the rest. Hispanics (which include other races according to Census definition) make about 1.5% of the total population. In Fall River County, the racial make-up was similar to Custer: 90.5% white, 6.1% Native American, with about 3.4% other races. Hispanics made up about 1.7% of the total population during this period.

Table 3.30: Current/Projected County Populations

	Fall River County	Custer County
1980	8,439	6,000
1990	7,353	6,179
2000	7,453	7,275
2005	6,563	7,677
2010	6,447	8,005

Sources: U.S. Department of Commerce 1990; 1997; 2000.
South Dakota State Data Center 1997.

Table 3.31: County Civilian Labor Force and Unemployment Rate

	Civilian Labor Force	Unemployment Rate
Fall River County		
1980	3,475	5.1%
1990	3,264	4.3%
1994	3,461	3.8%
Custer County		
1980	2,441	5.3%
1990	3,506	2.7%
1994	3,507	4.3%

Source: U.S. Department of Labor 1980; 1990; 1999.

Table 3.31 shows civilian labor force in the two counties and unemployment rates for 1980, 1990, and 1999. The labor force increased by more than 40% in Custer County from 1980-1990, while unemployment fell by almost 50%. For Fall River County, the labor force declined by 6.1%, unemployment declining by about 16%. The labor force decline was probably due to population loss in the county. The decline in unemployment could also have been due to the population loss, which included loss of unemployed people.

In Custer County, the labor force declined from 1990-1999 by about 2.4%, and the unemployment rate increased by 67%. This could be explained by the drop in employment in the manufacturing and government sectors of the economy. For Fall River, the labor force declined slightly, while unemployment fell by about 7%.

The number of households increased between 1970-1985 by more than 50% in Custer County (U.S. Department of Commerce 1990; 1997). Between 1985-1990, households declined about 6%, probably due to the decline in population from 1985-1990. Persons per household declined between 1970-1990 by about 12%, similar to declines in the State and the Nation. For Fall River County, households increased by 29% between 1970-1980, but the number of households declined by 5.3% between 1980-1990. This trend is similar to national population changes.

For both counties, the percentage of population 25 years and older who were high school or college graduates increased between 1980-1990 (U.S. Department of Commerce 1990). In 1990, 80.4% of the total population 25 and older in Custer County (4,138 people) graduated from high school, and 17.5% graduated from college. For Fall River County, 74.1% graduated from high school and 16.3% from college.

The percentage of the population below the poverty level declined in both counties between 1980-1990 (U.S. Department of Commerce 1990). For Custer County, the percentage declined by 13% between 1980-1990. For Fall River County, the percentage declined by about 30% during the same period.

County Economy

Income and Earnings

Table 3.32 shows personal income and total earnings (wages and salary, other labor income, and proprietors' income) for Fall River and Custer counties for 1985, 1990, and 1999. Total personal income in 1999 in Fall River County was $155.8 million (U.S. Department of Commerce 1969-2000). It increased by 7% between 1985-1990 and increased by 54% between 1990-1999. Per-capita income (income per person) in Fall River County in 1999 was $22,830, about 91% of the State average and 80% of the national average. Total personal income in 1999 in Custer County was $138.7 million. Personal income increased by about 26% between 1985-1990, and by about 54% between 1990-1999. Per-capita income was $19,739 in 1999 in Custer County, which was 79% of the State average and about 69% of the national average.

In Fall River County, total earnings in 1999 were $91.3 million (U.S. Department of Commerce 1969-2000). Between 1985-1990 earnings declined about 5% but increased by 41% between 1990-1999. Total earnings for Custer County in 199 were $67.5 million. Earnings increased 33% between 1985-1990, by 46.1% between 1990-1999.

Table 3.32 also shows earnings by industry for 1985, 1990, and 1999. In Fall River County, the larger industries based on earnings in 1999 were government; transportation, utilities, and communications; and services (U.S. Department of Commerce 1969-2000). In 1985, the largest industries had been government, services, and agriculture. Changes in earnings over the period show agriculture consistently declining. Between 1985-1990, agricultural services; finance, insurance, and real estate; and government sectors increased in earnings, while the remaining sectors declined. By 1999, earnings were greater than in 1990 for most of the industries in this county, with the exception of agriculture.

In 1999, the largest industrial sectors in Custer County were government, services, and trade, the same as they had been in 1985 and 1990. Changes in earnings during the period show the agriculture sector peaking in 1990 and falling in 1999; this is true for manufacturing, also. Transportation, utilities, and communications; construction; finance, insurance, and real estate; trade; services; and government sectors showed significant growth in earnings between 1980-1999.

Business Establishments and Employment

The total number of businesses, total employment, and employment by sector for both counties are shown in Table 3.33 for 1985, 1990, and 1999. In Fall River County, there were 224 business establishments with total employment of 3,964 full and part-time jobs in 1999. Between 1985-1990, business establishments decreased by 5.3%, total employment by about 1%. Between 1990-1999, business establishments increased by 24%, total employment increased by 6.1%. There were 222 business establishments in Custer County in 1999, and total employment was 4,002 full and part-time jobs. The increase between 1985-1990 in business establishments was 10.2 %, and in total employment 13.1%. Between 1990-1999, the increase in business establishments was 21%, total employment by 13.6%.

In Fall River County, the largest employers in 1999 were government (27%), services (22%), and trade (20%). Agriculture was the fourth largest employer in this county. The employment trend shows agriculture; transportation, utilities, and communication; and the government sectors declined in the past 10 years, while services; trade; and agricultural services, forestry, fish, and others increased.

Table 3.32: Personal Income and Earnings by Industry (Millions)

	Fall River County			Custer County		
	1985	1990	1999	1985	1990	1999
Total Personal Income	$94.18	$100.91	$155.80	$71.70	$90.08	$138.70
Total Earnings	$68.23	$64.88	$91.30	$34.68	$46.21	$67.50
Earnings by Industry						
Farm	$12.00	$5.47	$1.34	$0.53	$1.23	$1.80
Agricultural Services/Forestry/ Fish/Other	$0.30	$0.49	$0.69	$0.43	$0.22	$0.99
Mining	$2.42	$0.75	[1]	[1]	$0.58	$0.47
Construction	$2.01	$1.35	$3.72	$1.60	$3.03	$7.55
Manufacturing	$0.59	$0.54	$1.17	$3.25	$4.71	$2.37
Transportation/Utilities/ Commercial	$14.25	$13.75	$17.32	$2.27	$2.62	$5.27
Trade	$7.13	$6.89	$11.09	$5.25	$6.43	$10.09
Finance/Insurance Real Estate	$0.86	$1.07	$2.09	$0.53	$0.79	$2.07
Services	$6.19	$7.60	$12.66	$7.72	$9.15	$16.06
Government	$22.49	$26.96	$40.57	$11.29	$17.36	$24.42

[1] Information on earnings of this industry unavailable due to concerns about confidentiality; earnings included in total earnings for the year, however.

Source: U.S. Department of Commerce 1969-1999.

Table 3.33: Total Number of Businesses, Total Employment and Employment by Industry

	Fall River County			Custer County		
	1985	1990	1999	1985	1990	1999
Total Number of Businesses	190	180	[1]224	167	184	[1]222
Total Employment	3,761	3,736	3,964	3,118	3,526	4,002
Employment by Industry						
Farm	468	412	359	363	341	401
Agricultural Services/ Forestry/Fish/Other	39	56	52	37	52	90
Mining	83	55	[2]	[2]	65	35
Construction	137	118	188	[2]	182	303
Manufacturing	66	55	67	251	281	113
Transportation/ Utilities/ Communications	369	321	313	96	120	155
Wholesale Trade	27	30	[1]17	29	31	32
Retail Trade	602	626	805	501	601	789
Finance/Insurance/ Real Estate	125	96	150	137	154	256
Services	646	786	877	750	790	1,042
Government	1,199	1,181	1,088	726	909	786

[1] U.S. Department of Commerce 1998 estimate.

[2] Information on employment in this industry unavailable due to concerns about confidentiality; employment included in total employment for the year.

Sources: U.S. Department of Commerce 1969-1995; 1985-1995; 1999.

In 1999, the largest employers based on total employment in Custer County were services (26%), trade (21%) and government (20%). Agriculture was the fourth largest employer in this county also, with 10% of total employment. Employment trends show agriculture declining from 1985-1990 but increasing from 1990-1999. Transportation, utilities, and communications; trade; finance, insurance, and real estate; and services grew from 1985-1999.

Irrigated Agriculture

Table 3.34 shows the number of farms, irrigated acreage, and market value of crops sold for the two counties based on the U.S. Department of Commerce's *Census of Agriculture* (1992; 1997). Information was also obtained from Reclamation's annual summary reports and *Angostura Irrigation District Payment Capacity Study* (U.S. Bureau of Reclamation 1995). Total number of farms have increased in Custer County from 1987-1997. In Fall River County, the number declined from 1987-1992, then increased from 1992-1997. Irrigated acreage declined in both counties from 1987-1992 but increased from 1992-1997.

Most irrigation in Fall River and Custer counties is in the District. The District irrigates about 10,000 acres on average, with principal crops being alfalfa and corn. These provide a feed source for the livestock raised in the area. Each year an average of 28,000 AF of water from the reservoir is delivered to District lands, providing about 70% of the CIR on average. Without irrigation, crop production would be reduced to nothing some years, which would severely affect livestock production in the area.

Several factors were considered when evaluating regional economic impacts of changes in irrigation deliveries to the District. One was location of a feedlot in the District which depends heavily on irrigated corn and hay production from the District. The feedlot, with a 25,000-head capacity, requires 10,000-11,000 bushels of corn/day and about 16,000 tons of hay/year. The District supplies about 25-30% of the corn and hay, representing about 900,000 bushels of corn and 4,000 tons of hay annually. The feedlot therefore represents the primary source of demand for District crops and is thus critical to the local economy. The feedlot has about 1,000 acres of farmland, 70% irrigated. It directly employs 25 people and indirectly employs many more through its demand for local inputs. Gross sales from the feedlot—most of which comes from custom feeding—average a little more than $11 million annually, and net sales revenues are about $2 million annually.

The market value of agricultural products sold increased during 1982-1992. In Fall River County, which has a feedlot, livestock and poultry sales made up 96% of total sales. The feedlot is dependent on alfalfa hay and corn grown in the District. Livestock and poultry products made up 90% of total sales in Custer County.

Gross crop value had declined in the district from 1983-1993, but harvested cropland has increased. This may be due to falling market prices for crops grown in the District.

A regional impact analysis done for the *Angostura Reservoir Resource Appraisal Report* (U.S. Bureau of Reclamation 1996) estimated net impacts from irrigated agriculture in the District to the regional economy. (Net impacts are those under current irrigated conditions minus likely impacts with dryland crops). Farm production costs and income from the payment capacity study were used to estimate regional impacts.

The appraisal report did not fully account for regional impacts from the location of a large feedlot in the Angostura area. Changing the analysis to account for the feedlot resulted in estimated regional impacts of $2.32 million in

Table 3.34: Number of Farms, Irrigated Acres, Value of Crops and Other Information

Fall River County				Custer County		
	1987	1992	1997	1987	1992	1997
Total Number of Farms	339	298	309	303	323	326
Irrigated Acres	13,085	12,154	12,154	5,418	5,187	3,167
Market Value of Crops Sold (thousands)	$1,849	$2,835	$2,536	$715	$759	$1,181
	Average in District					
	1983	**1990**	**1993**	**1994**	**1990-1994**	
Total Irrigated Acres	12,218	12,218	12,218	12,218	12,218	
Harvested Cropland Acres	8,868	8,376	10,114	10,594	9,645	
Cropland Not Harvested and Soil Building Acres	2,576	1,717	120	91	423	
Dry-Cropped, Fallow or Idle Acres	476	1,827	1,686	1,228	1,850	
Farmsteads, Roads, Ditches, and Drains Acres	298	298	298	305	299	
Gross Crop Value (millions)	$2.23	$1.50	$1.81	Not available	Not available	
Number of Farms	70	78	70	Not available	Not available	

Sources: U.S. Department of Commerce 1992; 1997.
U.S. Bureau of Reclamation 1995.

total regional output, $540,000 in employee income, and 47 jobs annually. The benefits of irrigation to the Nation were estimated to be $520,000 annually (U.S. Bureau of Reclamation 1996).

Recreation

Recreational opportunities at Angostura Reservoir add to the regional economy. Table 3.35 shows annual recreation visitation and fees received between 1970-1996 (South Dakota Game Fish and Parks 1997). Lack of access below the dam discourages recreational use of the river, although there are some limited shoreline fishing, canoeing, and camping. Use is so minimal that it was not considered a factor in the recreational analysis.

Facilities—Recreation at Angostura is managed by SDGF&P under an agreement with Reclamation. About 1,500 acres on the east shore (see figure 2.1) of the reservoir have been classified a State Recreation Area, with campgrounds, boat ramps, marina, cabin area, day-use areas, and swimming beaches. The remaining 3,150 acres along the west and south shores are managed mainly for wildlife, although there are some boat docks and restrooms.

Visitation—On average, recreation visits increased over the 26-year period. Some declines occurred during droughts when water levels were low, most notably in 1976-1977 and again in 1988-1989. Recreation revenue increased most of the years between 1986-1996. In 1996, total recreational fees collected at Angostura Recreation Area were about $215,000.

Expenditures by non-local recreationists visiting the reservoir also contribute to the regional economy. Visitation in 1994 was divided by recreational activity, which was then matched to expenditures by recreation activity provided by the 1991 *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* (U.S. Fish and Wildlife Service 1992). The percentage of recreation by activity was obtained by using 1980 recreational use data collected at the reservoir (U.S. Bureau of Reclamation 1981). These data are believed to be reasonably accurate and is the best available for estimating current recreation use patterns. The percentages were used for activities other than camping (SDGF&P's Division of Parks and Recreation had already broken out that activity) to estimate 1994 visitation by recreational activity. Once this was done, the 1991 survey expenditure/visit by activity was multiplied by estimated 1994 visits by activity to develop a total expenditure per activity. Expenditures were adjusted to account for only dollars spent by recreationists who reside outside the Angostura area. From this data, regional impacts were developed using techniques similar to those used to estimate irrigation impacts discussed above.

Recreational activities at the reservoir include boating, camping, fishing, hunting, picnicking, day use, swimming, bicycling, hiking, and bird watching. Since the early 1970s, Angostura has experienced steady visitation growth (Table 3.35), reaching a record high of 293,000 in 1979 (South Dakota Game Fish and Parks 1992).

Regional impacts from recreational activities in 1994 were estimated to be $3.41 million in total regional output, $1.20 million in employee income, and 92 jobs annually. Recreational benefits from the reservoir to the Nation were estimated to be approximately $7.1 million annually based on a travel cost model developed for the appraisal study (U.S. Bureau of Reclamation 1996).

Table 3.35: Recreation at the Reservoir, 1970-1996

Year	Day Use (Visitor-days)	Camping (Visitor-days)	Total Visits (Visitor-days)	Annual Increase in Visits (%)	Revenue from Recreation Fees
1970	90,136	7,260	97,396		[1]
1971	92,526	14,484	107,010	9.87	[1]
1972	91,101	18,932	110,033	2.82	[1]
1973	100,005	23,924	123,929	12.63	[1]
1974	105,700	25,120	130,820	5.56	[1]
1975	192,860	18,847	211,707	61.83	[1]
1976	216,156	20,712	236,868	11.88	[1]
1977	207,275	17,270	224,545	-5.20	[1]
1978	205,429	21,961	227,390	1.27	[1]
1979	266,769	26,240	293,009	28.86	[1]
1980	247,969	25,271	273,240	-6.75	[1]
1981	245,216	24,045	269,261	-1.46	[1]
1982	243,447	23,168	266,615	-0.98	[1]
1983	233,438	22,541	255,979	-3.99	[1]
1984	241,875	21,360	263,235	2.83	[1]
1985	245,567	18,523	264,090	0.32	[1]
1986	223,937	18,469	242,406	-8.21	$73,843
1987	214,813	20,950	235,763	-2.74	$80,699
1988	222,548	17,129	239,677	1.66	$77,224
1989	190,701	11,744	202,445	-15.53	$59,296
1990	206,155	14,808	220,963	9.15	$81,475
1991	241,759	19,148	260,907	18.08	$113,099
1992	269,970	21,981	291,951	11.90	$141,167
1993	184,870	26,699	211,569	-27.53	$155,369
1994	240,767	30,316	271,083	28.13	$202,061
1995	230,723	32,956	263,679	-2.73	$204,407
1996	260,038	30,731	290,769	10.27	$214,497

[1] Revenue information available for 1986-1996 only.

Source: South Dakota Game, Fish and Parks 1997.

Population Characteristics of the Pine Ridge Reservation

Total land area of the Pine Ridge Reservation is 2.4 million acres, of which 1.8 million is Tribal trust and individual Indian allotted lands. Before the 1980 Census, the Reservation contained part of Washabaugh County, but this has since been combined into Jackson County. Part of the Badlands National Park is also within the Reservation and Buffalo Gap National Grasslands lies just to the west.

Two sources of the Reservation population were used: Census data—as used for Fall River and Custer counties earlier in this section—and BIA's (U.S. Bureau of Indian Affair's) *Labor Market Information on the Indian Labor Force* (1991; 1995; 1997). Census estimates in rural areas, including many Indian reservations, can significantly underestimate true population. Underestimation can result from missing households or inaccuracies in counting the number of people in each home. The number of reservation people/household reported by the Census is frequently lower than estimates provided by tribes and other agencies. Hence, BIA data was added to this section. The BIA reports were compiled from surveys done by 544 U.S. tribes, and are certified by tribal leaders as accurate. They record the reservation's *service population*, the population available for work. While the accuracy of this data also has been challenged, the BIA reports serve to indicate population trends on the Reservation over a period of time from a source other the Census.

Table 3.36 shows total Reservation population according to 1970, 1980, 1990, and 2000 Censuses, as well total Reservation service population according to the BIA reports. (The 2010 estimate is based on the 1988 University of South Dakota Business Research Bureau projections for Shannon County and 55.5% of Jackson County's projected growth.)

Reservation population has increased significantly over the past decade according to both sources: 39% by Census data, 89% by BIA data. Projections to 2010 indicate continued growth of the Reservation population, significantly higher than growth in Fall River or Custer counties.

Table 3.36: Reservation Population

		By County			
Year	Total	Shannon	Washabaugh	Jackson	Bennett
1970	12,675	8,198	1,389		3,088
1980	16,273	11,323		1,906	3,044
1990	11,179	8,724		1,078	1,377
2000	15,507	[1]		[1]	[1]
2010	19,113				

[1] Reservation population per county was unavailable at the time this was written.

Sources: U.S. Department of Commerce 1990; 1997.
South Dakota State Data Center 1997.

The Census estimated that there were 2,571 households on the Reservation in 1990 and there was an average of 4.4 people/household (U.S. Department of Commerce 1990). Of the total housing, about 46% were owner-occupied; the median value of owner-occupied housing was about $15,000. About 1,400 units were under some type of rental contract. About 23% of all housing lacked plumbing, while 90% had water service from public or private systems or from a well.

In 1990, 4,932 people on the Reservation were enrolled in school. High school graduates and those with higher education made up 58.5% of the population (9% with a bachelor's or higher college degree). About 92% of the Reservation population is Native American, with the rest either white or Hispanic.

Economy of the Reservation

The 1990 Census estimated per-capita income on the Reservation to be $3,520, compared to $10,661 for South Dakota and $14,420 for the Nation (U.S. Department of Commerce 1990). The same pattern of low income is reflected through 1990 Census estimates of median household income, estimated to be $11,255, compared to $22,503 for the State and $30,056 for the U.S. The 1990 Census estimated unemployment to be 29.4% on the Reservation, compared to 4.2% in the State and 6.3% in the U.S. About 63% of the Reservation population was below the poverty level, in comparison to 11.85% of the Custer County population, 12.84% of the Fall River population.

In addition, a little over 44% of the Indian population did not have a high school degree or the equivalent in 1990, compared to about 23% for the State and 24.8% for the U.S.

Census estimates probably underestimate the true unemployment on the Reservation because of how unemployment is defined. Once people stop seeking employment, they are no longer considered to be in the labor force and are thus not counted as unemployed. Slightly more than 50% of the Indian population 16 years and older on the Reservation was not considered to be part of the labor force in the 1990 Census. This is a large percentage (about 33.8% of those 16 years old and older in South Dakota are not part of the labor force), and a significant part of this 50% on the Reservation not considered part of the labor force are chronically unemployed and have given up finding work. This fact—combined with potential under-employment problems where those who have part-time jobs would like full-time jobs—results in unemployment much higher than the 1990 Census figures indicate.

According to BIA data, the total labor force on the Reservation numbered 22,840, 6,198 of whom were employed (U.S. Bureau of Indian Affairs 1998). The Reservation unemployment rate in 1997 was about 73%, in comparison to 4% for Fall River County and 4.5% for Custer County. About 52% of the labor force (4,800 people) earned $9,048 or more per year (U.S. Bureau of Indian Affairs 1995).

A number of service and retail businesses can be found on the Reservation, and Federal programs provide some jobs as well as services. The Oglala Lakota College also provides employment. Other business operations—such as Cedar Pass Lodge in Badlands National Park, bingo operations, and the Prairie Wind Casino 12 miles west of Ogallala—are owned and operated by the OST, contributing to the Reservation economy.

There could be economic connections between the District and the Reservation, such as in jobs and earnings of OST members associated with irrigated agriculture in the District and with the feedlot. While this analysis was unable to quantify these jobs, earnings, or other economic connections, it is still recognized that there might be some and that these economic connections could be affected by the alternatives.

Red Shirt

Information was provided by the town manager on population, demographic data, employment, schooling, and housing in Red Shirt. The 1998 population was 240 people, having increased only slightly over the past 10 years (Chris Eaglehawk 1998: personal communication). Employment in the town comes mostly from agriculture (ranching), government agencies (Tribal, State, and Federal), and the Tribal casino. Limited employment is also provided by the local cottage industry producing traditional Native American crafts and art.

Housing in the town consists of 40 units, 22 of which are owner-occupied, the rest rental units. Most are multi-dwelling units. The Shannon County Elementary School in Red Shirt educates kindergartners to 8th graders, while high school students are bused to nearby county schools.

Social and economic conditions on the Reservation are worse in comparison to conditions in Fall River or Custer counties. The Reservation has a high level of unemployment, greater infant mortality, percentage of people living below the poverty level, and less owner-occupied housing when compared to South Dakota or the Nation as a whole, based on the 1990 Census and 1995 Census update.

INDIAN TRUST ASSETS

ITAs (*Indian Trust Assets*) are properties, interests, or assets of an Indian tribe or individual Indian over whom the Federal Government also has an interest through administration or direct control. Examples include lands, minerals, and timber, as well as water rights, hunting rights, fishing rights, and other treaty rights. The sovereignty of tribes and the trust relationship with the Federal Government have been established and validated through treaties, court decisions, legislation, regulations, and policies. Reclamation's policy on ITAs is that impacts must be determined and considered when implementing Reclamation actions.

One of the objectives of consultations with the OST, CRST, and LBST (Lower Brule Sioux Tribe), and public meetings on the reservations was to identify concerns the tribes might have with ITAs (see Chapter 5). Meetings determined three ITA concerns: Water rights, culturally important plants, and fisheries.

Water Rights

As explained in Chapter One "Water Rights," Indian water rights are based on the Winters Doctrine. This doctrine states that enough water was reserved (set aside) when Indian reservations were established to fulfill purposes for which the reservations were originally created. The priority date for reserved water rights are the date on which the particular reservation was established.

The OST and the CRST have claimed water of the Cheyenne River under the Winters Doctrine. The LBST has also claimed water of the Cheyenne under the Winters Doctrine and the 1868 Treaty. The Pine Ridge Reservation and the Cheyenne River Reservation were established before the claims of most other appropriators in the basin which means they would have priority.

The fact that neither Tribe has exercised their rights does not negate their reserved water rights under the Winters Doctrine to water in the river. If the Tribes eventually exercise their reserved rights and put the water to beneficial use, the volume of water available for other users in the basin might be affected.

Culturally Important Plants

The OST voiced concerns about possible changes in the local abundance and distribution of plants traditionally used by the Tribe. Many believe changes in traditional plants can be linked to the Angostura Unit. The plants are American plum (*kante*), silver buffaloberry (*mas`tinca pute´can*), and common chokecherry (*canpa`hu*). These plants are shrubs-to-small-trees, ranging throughout central and eastern North America. Locally, American plum generally forms small thickets along drainage-ways or in sheltered prairie depressions (Johnson and Nichols 1982). Common choke-cherry forms thickets along fence rows or valley bottoms and occurs as scattered understory in open woods. Both chokecherry and American plum are considered quite drought resistant. Silver buffaloberry is scattered, frequently occurring along streams, on moist hillsides, and in bottom lands. The small fruit from these three species has value to both people and wildlife.

Traditionally, the Lakota used these plants for food and medicines (Gilmore 1977; Hassrick 1964; Kindscher 1996). Both Gilmore and Kindscher reported that the Lakota used the sprouts of wild plum in making *wau^{n}ya^{n}pi*, an offering or form of a prayer, especially for the benefit of the sick. Wild plum was also used for food (Hassrick 1964). Further, August is referred to as "Moon of the Ripe Plums" (Hassrick 1964).

Buffaloberry was used for food and dried for use during the winter (Gilmore 1977). It was also used ceremonially in feasts and had some minor medicinal uses (Kindscher 1996).

Chokecherry was probably the most important of the three plants to the Lakota economy (Gilmore 1977; Kindscher 1996). It was especially valued as food, a favorite being as the major fruit in *wasna*, a form of pemican (Gilmore 1977; Kindscher 1996). It was occasionally used for arrow shafts (Hassrick 1964), to make mush, and for tea (Kindscher 1996). It also had medicinal uses such as for the treatment of minor stomach ailments and as a poultice to stop bleeding (Kindscher 1996).

Chokecherries were also used in female puberty ceremonies and the White Buffalo Ceremony (Hassrick 1964). The time of the Sun Dance was determined by the ripening of the cherries and, in this respect, the month of July is referred to as "Moon of Ripening Chokecherries" (Gilmore 1977; Hassrick 1964).

Authorities and scientific literature indicate the reported decline in local abundance, and distribution of the three plant species probably is not linked to changes in the river from construction of Angostura Dam. Only common chokecherry was found on a list of plants compiled by USFWS as occurring in wetlands (1988). The list defines chokecherry as a plant that usually occurs in non-wetlands (67-99% of the time), but occasionally can be found in wetlands (1-33% of the time). *Prunus* species (plum and chokecherry) require well drained soil, a condition more common in upland sites. Buffaloberry is more likely found associated with green ash communities on drier upland sites, rather than with cottonwood/willow communities in riparian sites. Thus, while these plants may occur near streams, they are correctly characterized as upland species.

Reported declines in abundance or distribution of plum, chokecherry, and buffaloberry are likely due to land-use changes. All three have only limited value as forage, although livestock may eat the leaves and twigs of the plants when more palatable forage is limited. Buffaloberry is sensitive to grazing, and plum and choke-cherry may also decline if grazing pressure is severe. Chokecherry, however, may be toxic to livestock if consumed in large quantities (Johnson and Nichols 1982).

Livestock congregating near streams or other water sources may also affect plant communities by trampling or by compacting the soil. Grazing data were not available for analysis, but livestock use of the stream corridor of the river may have contributed to declines in the local abundance and distribution.

Fire is another factor that may affect abundance and distribution of the three plants. In prairie grasslands, fire tends to suppress or eliminate woody plants. Most *Prunus* species are generally fire resistant, although burning during the growing season and frequent fires may adversely affect chokecherry. Fire suppression policy may favor increased abundance of these species. As with grazing, fire management data were not available, but it is likely that fire has played a role in local abundance and distribution of these plants.

It appears unlikely that reported declines in local abundance and distribution of American plum, common chokecherry, and buffaloberry on the Reservation are linked to the Angostura Unit. These three plants are generally considered upland species and thus occur beyond the influence of the dam. Decline in abundance and distribution is likely related to land management practices on the Reservation, such as grazing and fire.

Fisheries

Because the Ft. Laramie Treaty of 1851 recognized the right of the Lakota to continue to fish in ceded lands, fishing thus meets the definition of an ITA. Article 5 of the treaty recognized that fishing was an economic activity to which they were entitled to continue to pursue:

> It is, however, understood that, in making this recognition and acknowledgment, the aforesaid Indian nations do not hereby abandon or prejudice any rights or claims they may have to other lands; and further, that they do not surrender the privilege of hunting, fishing, or passing over any of the tracts of country heretofore described.

The historic Lakota economy revolved around buffalo hunting, and discussions about the subsistence economy have focused on buffalo, as well as antelope and deer (Howard 1980; Hassrick 1964). Only minimal attention has been given to fish in the Lakota's subsistence (Howard 1980; Rustlund 1952). Rustlund (1952), in his overview of fishing among the tribes, did not associate any specific fishing technology to the Lakota, Howard (1980) associated fishing more with the Santee and Middle Dakota than the Lakota Sioux; the latter considered fish "unclean." Both the Santee, Yankton, and Yanktonai Dakota Tribes made use of weirs to catch fish. Archaeological evidence (including both a weir and fish bone) from the Dirt Lodge Site (39SP11), a historic Santee Sioux site on the James River in Spinks County, South Dakota, supports this view (Haberman 1983).

Hassrick (1964) contradicted somewhat Howard's downplaying of fish in Lakota subsistence. Fishing was done with a hook, spear, or a rawhide blanket in which holes were punched to serve as a net. Suckers were among the fish used historically. Hassrick (1964) cited an informant who reminisced about catching suckers with a spear or pole and noose. Hassrick (1964) included a drawing of a fish spear and a rawhide blanket net.

The CRST conducted an ethnographic analysis of the importance of fishing to Tribal members for this EIS (see Appendix Y). Walker listed

38 species (both native and introduced) as culturally significant. Most are used for food, especially among economically disadvantaged Tribal members. Walker also stated that fish have religious significance; they are the focus of the "Feast of the Raw Fish," a major ceremony.

Further evidence of fish in Lakota subsistence comes from cognates for the word "fish." Table 3.37 shows Lakota cognates for fish, specific fish species, and activities associated with fishing. The Lakota have words for several species of fish present in the Cheyenne River or nearby drainages (Everman and Cox 1896). That the Lakota distinguished these different species and had distinct cognates for different fishing activities indicate that fishing did play a role in their subsistence economy.

Table 3.37: Lakota Words Associated with Fish

Fish and Fish Species	
English	**Lakota**
fish	***Hogaη***
carp	***Hoiwotka, hosaη***
catfish	***Howasapa***
eel	***Hoka, zuzuecahongaη***
grass pike	***Hogleglega***
rainbow	***Hogleglega***
red-fin	***Hoapes´a***
shad	***Holaska***
Fishing Activities	
fish hook	***Cakiyuh´late, hoicuwa, hoipate, hoiupsiu***
to fish	***Hokuwa***
to collect fish	***Homnayη***
to spear fish	***Hopataη***

Source: Buechel 1983.

As noted in the "Fisheries" section in this chapter, the Cheyenne River below the dam to the confluence with the Belle Fourche River is typical of western streams after regulation. Water is colder there than downstream and less turbid. Fish species requiring turbid water are found less frequently or not at all, having been replaced by fish species preferring clear, less turbid water. The fish health analysis found measurable concentrations of seven insecticides and one herbicide in fish in the river. Six of the insecticides are now banned, so the concentrations are assumed to be residue from past use. The other insecticide is not known to be in use in the District. The herbicide, by contrast, is in use in the District, but concentrations in fish above the District are greater than those downstream. Concentrations of heavy metals were well below EPA's Fish Advisory Screening Values.

ENVIRONMENTAL JUSTICE

Executive Order 12898 signed February 11, 1994, requires Federal agencies to identify and address "Disproportionately high and adverse human health and environmental effects of its programs, policies, and activities on minority populations and low-income populations." Federal agencies must consider whether impacts of their activities place an undue burden on low-income or minority populations in regard to the environment or human health. No person or group should shoulder a disproportionate share of negative environmental or human health impacts associated with the implementation of a Federal program, policy, or activity.

Compliance under the Executive order in regard to Native Americans is addressed in Section 6-606:

> Each Federal agency responsibility set forth under this order shall apply equally to Native American programs. In addition the Department of the

Interior, in coordination with the Working Group, and, after consultation with tribal leaders, shall coordinate steps to be taken pursuant to this order that address federally-recognized Indian Tribes.

Reclamation prepared this EIS in part because of a request from the Oglala Sioux Tribal Council. Scoping meetings have been held on the Pine Ridge, Cheyenne River, and Lower Brule Reservations, and the Re-Establishment of Natural Flows Below the Dam Alternative was developed to address Tribal concerns. Further, Reclamation contracted with the OST to provide information for this EIS. Impacts to the Tribes, including those to social and economic conditions and to ITAs, are analyzed in the EIS.

It should be noted that the EIS considers impacts of contract renewal and water management on the current and future environment of the Cheyenne River basin and health conditions of low income or minority populations. It does not consider past impacts dating from construction of Angostura Dam.

As required by CEQ (Council of Environmental Quality) regulations, environmental justice has been evaluated according to three criteria: Whether impacts are significant or above generally accepted norms; whether contract renewal and water management pose a significant environmental hazard to a minority or low income group which appreciably exceeds the risk to the population in general; and whether impacts, when combined with effects of other projects, pose a cumulative environmental hazard to a minority or low income group.

CULTURAL RESOURCES

Cultural resources are archaeological, historical, or architectural sites, buildings, structures, objects, and districts, or properties of traditional religious and cultural importance to Native Americans, based on the definition in NHPA (National Historic Preservation Act). Section 106 of the act specifies that Reclamation, as the Federal agency responsible for the contract, must consider the impacts of the alternatives on historic properties. In addition, comments were received from the public on effects of the alternatives on cultural resources.

For purposes of this EIS, the Angostura area was defined as Reclamation-administered lands at Angostura Reservoir, the District, and the Cheyenne River downstream from the dam to the west boundary of the Cheyenne River Reservation. This last area was further delineated to the first terrace (T1) immediately next to the flood plain on both sides of the Cheyenne River. Impacts would be unlikely to extend beyond T1. The area encompasses two regions in the South Dakota State Plan for Archeological Resources (Winham and Hannus 1991): The South Fork Cheyenne River and the Central Cheyenne Archeological Regions. The South Fork Cheyenne region is probably better known than the Central Cheyenne region, because of investigations at Angostura Reservoir summarized in Reclamation's appraisal report (1996).

Investigations in the South Fork Cheyenne Archeological Region—especially those associated with the Smithsonian River Basin Survey for Angostura Reservoir—contributed greatly to knowledge of the region. In contrast, few investigations have been conducted in the Central Cheyenne Region, so knowledge of the region is necessarily less.

Cultural History of the Angostura Area

The cultural history of the area can be divided into four periods (Table 3.38). These periods are those generally employed when discussing archaeology of South Dakota and the northern Great Plains (Winham and Hannus 1991; Frison 1991). Each period is distinguished by specific artifact types and, in some instances, site types. Sites and objects representative of each of the periods have been found in the Angostura area.

Paleo-Indian occupations are identified by skillfully crafted projectile point types—Clovis, Folsom, Plainview, Goshen, Angostura, among others—and are best known from kill-sites containing remains of late Pleistocene fauna. Paleo-Indian artifacts have been found in and next to the area. The Ray Long Site (Winham and Hannus 1991) and two more Paleo-Indian sites are at the reservoir.

Evidence for the succeeding Archaic Period is more widespread than for the Paleo-Indian Period. The Archaic Period is distinguished by appearance of a unique set of projectile point types and stone tools.

Except for materials associated with the Early Archaic, evidence for Archaic Period occupation is fairly widespread in the region; 18 sites were found at the reservoir, (Haug et al. 1992). The Late Prehistoric Period is distinguished by a new set of projectile points and the appearance of ceramics. Twenty-four sites of this period can be found at the reservoir. Several suggest fairly intensive occupation over a long period of time. The most distinctive type associated with this period is the *earthlodge village*, which consists of the remains of permanently occupied settlements.

The final period, the Contact/Historic Period, begins with the appearance of Euroamerican trade items in Native American occupation sites. Historic accounts of explorers, traders, and missionaries indicate that a number of tribes either occupied or were present in the area early during this period, including the Lakota, Pawnee, Sioux, Apache, Kiowa-Apache, Kiowa, Cheyenne, Arapaho, Crow, and Ponca (Schlesier 1994). Historic Euroamerican sites include trading posts, cabins, military sites, farmsteads, churches, early reservation housing, and/or features associated with early irrigation. More recent historic structures include Angostura Dam and the facilities associated with the District.

Table 3.38: Prehistoric/Historic Periods Represented in the Angostura Area

Period	Duration	Description	Sites
Paleo-Indian	12,000- 8,000/ 7,500 years bp (before present)	Nomadic hunter-gatherers who exploited Pleistocene fauna	Ray Long Site
Early Middle Late Archaic	8,000/ 7,500- 2,000/ 1,500 years bp	Nomadic, generalized hunter-gatherers who exploited modern animals and plants. Used the atlatl	Includes occupation sites and lithic scatters
Late Prehistoric	2,000/ 1,500 years bp, circa 1750 AD	Increased sedentism, introduction of horticulture, ceramics, and bow and arrow	Includes artifact scatters, rock-shelters, stone circles, and earthlodge villages
Contact and Historic	circa 1750 AD to Present	Advent of Euro-americans and Euro-american technology into the area	Trading posts, post-1850 farmsteads and early irrigation systems

South Fork Cheyenne Archeological Region

The South Fork Cheyenne Archaeological Region includes the upper end of the Cheyenne River basin. It is bounded on the west by the Black Hills and includes southeastern Meade County and parts of Pennington, Custer, and Fall River counties (Winham and Hannus 1991). The first systematic surveys of the region were done by the SI-RBS (Smithsonian Institution-River Basin Survey) in conjunction with construction of Angostura Dam. Investigations at the reservoir can be divided into two periods: The first, defined by SI-RBS investigations, taking place in the late 1940s before construction (Bauxar 1947; Hughes 1949; Wheeler 1995; White and Hughes 1948). Beginning in the 1980s, the second period of investigations occurred, spurred primarily by Reclamation's operation, maintenance, and administration of the reservoir and nearby public lands (Haug et al. 1987; Haug et al.1992; Lippincott 1996; Hannus 1986; Hannus et al. 1993).

A total of 112 prehistoric and historic sites have been recorded on lands administered by Reclamation around the reservoir (see Appendix X). Of these, 100 are prehistoric sites, 4 are historic sites (buildings or structures), 5 have both prehistoric and historic components, and 3 are paleontological sites with possible evidence of prehistoric occupation. Occupation sites, lithic scatters, stone circle sites, rockshelters, and paleontological sites are the prehistoric sites present. Occupation sites are scatters of artifacts, bone, occasional pottery shards, and fire-cracked rock, assumed to be occupied over an extended time. Lithic scatters are distinct accumulations of stone (lithic) tools and/or debris from their manufacture. (Artifact densities at such sites are generally low.) This category includes the *workshop site* type mentioned in some literature (Haug et al. 1987). Stone circle sites—also called *tipi rings*—are distinguished by one or more circular stone alignments thought to have held down lodge flaps. Rockshelters are occupied rock overhangs. Paleontological sites contain only remains of Quaternary Period animals but are presumed to be the result of human activity. Historic sites consist almost exclusively of farmsteads and/or features associated with early irrigation systems. All are post-1850 in age and are associated with the appearance of Euroamericans in the area.

Following the 1987 investigations at the reservoir (Haug et al. 1992), Reclamation consulted with the South Dakota SHPO (State Historic Preservation Office) about NRHP (National Register of Historic Places) eligibility for these sites, as required by the National Historic Preservation Act (Appendix X). Sites 39FA75 and 39FA91—rockshelters with petroglyphs—are currently included in NRHP. There was agreement that another eight sites, including 39FA65, the *Ray Long Site*, also qualified as historic properties although they have not been formally nominated to NRHP. The potential of seven other sites needs to be evaluated; existing data are insufficient for determination. Sixty-five sites do not qualify as historic properties, including some SI-RBS sites that could not be relocated during the 1987 investigations. These sites are presumed destroyed. Should any of them be relocated in the future, they will have to be evaluated.

Reclamation and SHPO also have agreed that Angostura Dam qualifies for inclusion in NRHP, considered eligible because of its exceptional importance to water delivery and development of irrigation in the region and the fact that it was the first dam completed under the Pick-Sloan Missouri River Basin Program. Determination for the NRHP has not been completed.

The District is also within the South Fork Cheyenne Archaeological Region. However, cultural resources there are not as well documented as those around the reservoir.

Several inventories have been done in or next to the District (Hughes 1949; Miller 1981; Miller and Crossan 1981; Messerli 1986; Buechler 1986, 1987, 1989; Gonzalez 1989; Vallejo 1989; Quivik and Johnson 1990; Noisat 1992; Kangas 1998). Most investigations, though, were not done in conjunction with projects directly related to operation and maintenance of the irrigation system.

The result is that only a small part of the total District has been inventoried. Only two occupation sites and two historic structures have been identified in or next to the District. The two occupation sites (39FA888 and 39FA714) consist of scatters of prehistoric stone artifacts. Site 39FA888 has been determined not to qualify for NRHP, while there has been no determination on Site 39FA714. The historic structures consist of a cabin (39FA881) and a steel truss bridge (Structure 17-496-252). Both have been determined eligible for inclusion in the NRHP.

Considering the limited inventories in the District, these sites cannot be considered representative of the total number present. Except for Structure 17-496-252, similar types have been recorded in and around the reservoir. Since the District is also next to the Cheyenne River, more complete inventories of the area could be expected to encounter site types and densities comparable to those found around the reservoir.

Reclamation and SHPO are discussing including the canals and laterals for inclusion in NRHP because of its exceptional importance to development of irrigation in the region. Determination has not been completed.

Central Cheyenne Archaeological Region

The Central Cheyenne Archaeological Region consists of the Cheyenne River valley and associated terraces, breaks, and nearby plains (Winham and Hannus 1991). The Cheyenne River was a major route linking the Missouri River with the Black Hills. Cherry Creek and Cheyenne City, located at the end of the region, were important centers during the Ghost Dance Movement of the 1880s and 1890s. Several camps along the river have been associated with historic Sioux leaders and elders like Big Foot, Bear Eagle, Red Shirt, Touch the Clouds, Hump, and Corn (Anderson 1956; Winham and Hannus 1991). All were important in the Ghost Dance Movement and its tragic culmination at the Wounded Knee massacre. Although the region contains several historically significant sites, it has not received the archaeological attention of the South Fork Cheyenne Archaeological Region. The surveys are listed in Appendix X, most of which were small-scale and involved only small acreages.

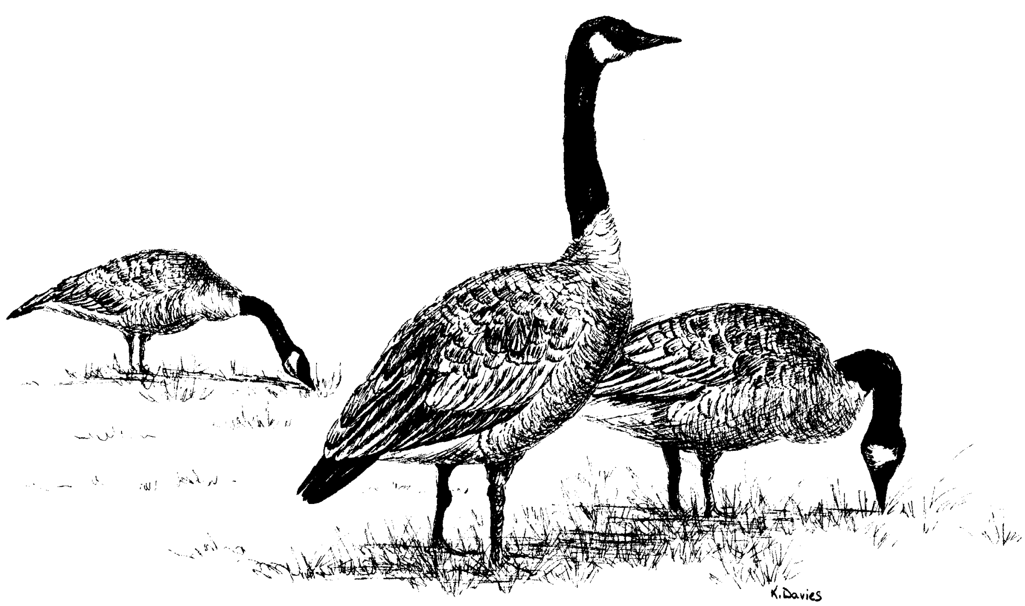
The earliest systematic inventories were SI-RBS reconnaissance surveys of the area to be inundated by Lake Oahe, including around the mouth of the Cheyenne River. Results of these surveys, though, were poorly reported. In 1988, archaeologists from Augustana College inventoried more than 19,000 acres at the lower end of the river managed by the U.S. Army Corps of Engineers (Winham et al. 1988), representing an expansion of investigations originally done by SI-RBS. This inventory extended into the Central Cheyenne Archaeological Region.

The inventory discovered 79 sites, 10 of which were in the Central Cheyenne Region (Appendix X). Most are in the uplands outside of the Angostura area. Sites include nine rock cairns, three associated lithic artifact scatter, and a lithic scatter. They were recommended as potentially eligible for the NRHP. Winham et al. 1988 also identified four previously reported historic sites, including three buildings and one school/farmstead. The inventory unfortunately did not include the flood plain of the river, the focus of this EIS.

The most comprehensive inventory was done by SARC (South Dakota Archaeological Research Center) in 1992. It involved an on-the-ground survey of 3,835 acres in selected parts of the river basin and the lower reaches of tributaries (Fosha 1992), including the eastern part of the Central Cheyenne Archaeological Region and the western part of the Bad/Cheyenne Archaeological Region. Most of the inventoried areas are downstream of the EIS area. SARC recorded 41 sites, 31 in the Central Cheyenne Region. Nine prehistoric site types were encountered, including nine prehistoric occupation sites/artifact scatters, six prehistoric cairn sites, two prehistoric stone circle sites, an historic artifact scatter, a site with both a prehistoric and historic artifact scatter, one historic and three prehistoric isolated finds, a prehistoric hearth, a faunal site, an earthlodge village (the Elmer Briggs Village), four historic farmsteads/cabins, and a site consisting of both a historic farmstead and prehistoric artifact scatter.

The archaeological periods represented by these sites include Middle Archaic, Late Prehistoric, Contact, and Historic. A possible Paleo-Indian occupation may be represented by an isolated hearth and bison bone exposed in a cut bank. The associated landform consists of late Pleistocene or Early Holocene alluvial cut and fill inset on what appears as a Pleistocene terrace. The village site (Elmer Biggs/39HK36) contains 13 circular depressions, 2 stone cairns, 1 stone circle, and 1 metate. Subsurface probing of a depression revealed burned earth, burned bone, and charcoal. A historic component includes a rectangular stone alignment (assumed to be the foundation of a structure), a cabin, a rectangle depression, and a cistern.

Fosha (1992) recommended that seven of these sites—including the Elmer Briggs Village site—may be eligible for the NRHP. Another two sites were considered ineligible, with eligibility of the remaining 23 sites unknown.



Sites types present in the Central Cheyenne River Archaeological Region do not appear to differ substantially from those in the South Fork Cheyenne River Region. The presence of rockshelters in the western part of the South Fork Cheyenne River Archeological Region and their absence in the Central Cheyenne Region may reflect differences in geologic setting. The absence of earthlodge villages in the South Fork Cheyenne River Region may only reflect the lack of surveys there. Further work should produce data necessary for more conclusive comparisons between these two regions and with other nearby regions.

Properties of Traditional Religious and Cultural Importance to Native Americans

The NHPA was amended in 1992 to recognize that sites of religious or cultural importance to Native Americans can qualify as historic properties. Commonly called *Traditional Cultural Properties* (TCPs), these sites often differ from other cultural resource sites because they may often lack physical remains like artifacts, or they may be of recent origin. Such sites are often identified through non-archaeological methods. TCPs are especially critical because of the historic tie between the Lakota and this region of South Dakota. Sundstrom (Sundstrom and Keyser 1984; Sundstrom, 1996) has documented the TCPs in the Black Hills and their significance, especially rock art sites. Two rockshelters at Angostura (39FA75 and 39FA91) have petroglyphs and, as such, may constitute TCPs. Consultation with Native American groups could determine whether they are properties of traditional religious and cultural importance and, therefore, qualifying as historic properties.

To assist in identifying TCPs, Reclamation contracted with the OST to interview Tribal elders and traditional leaders. Personal interviews were conducted with individual elder Tribal members who still reside in the area or may have historic or traditional knowledge. These interviews focused on aspects of traditional and historic uses of the Cheyenne River since construction of Angostura Dam.

PALEONTOLOGICAL RESOURCES

Comments were received from the public about effects of the alternatives on paleontological resources, fossil remains of plants and animals, both invertebrate and vertebrate. (Dr. Gordon Bell of the South Dakota School of Mines and Technology's Museum of Geology supplied information used in this section.)

Paleontological resources, like cultural resources, are subject to natural forces such as plant growth, erosion, and slope angle, in addition to human activities. They affect paleontological resources and the ability to locate and identify fossil localities. They can either promote preservation or destruction. For this reason, the area of concern for paleontological resources was the same as for cultural resources: Reclamation-administered lands at the reservoir, the District, and the Cheyenne River downstream from the dam to the west boundary of the Cheyenne River Sioux Reservation. This last area extends to the first terrace (T1) immediately next to the flood plain on both sides of the Cheyenne River. Impacts would be unlikely to extend beyond T1.

Paleontological resources have not received scientific or management attention in the EIS area as have cultural resources. No detailed analysis or summary is available. Few paleontological investigations have been done there, with most of those having being done in conjunction with construction and operation of the dam and reservoir. For this reason, this discussion focuses on data from the dam and reservoir, which is used to evaluate potential for paleontological resources elsewhere in the basin and on possible impacts.

One of the earliest investigations at Angostura was done by SI-RBS in conjunction with construction of the dam and reservoir (Bauxar 1947). The SI-RBS did a preliminary appraisal of paleontological resources to determine if any major finds might be impacted. None were reported.

In 1994, fossilized remains of a mosasaur (*Platecarpus* species) were discovered eroding out of the Sharon Springs Member of the Pierre Shale at the southern end of the reservoir, overlooking Horsehead Creek. The Museum of Geology, South Dakota School of Mines and Technology, evaluated the remains, which consisted of a single vertebrae, several ribs, the proximal part of the right forelimb, and the pectoral girdle. Exposure caused the bone material to be in poor condition, being soft and powdery (Bell 1995a). No further work was recommended on the fossil.

Spurred by this discovery, Reclamation signed a contract with the museum to appraise the paleontological resources at the reservoir (Bell 1995b). The appraisal involved a review of existing data, a preliminary field assessment of specific locations considered likely to contain fossils, and a discussion of the geological strata around the reservoir in relation to potential to contain significant fossils.

During the field check, the remains of a Plesiosaur (*Bracaunchenius* species) and a teleost fish (*Pachyrhizodus leptopsis*) were found at the southern end of the reservoir, overlooking the confluence of Horsehead Creek and the Cheyenne River. The remains were excavated in 1996 (Bell 1997). The Plesiosaur remains consist of a well preserved skull, one of less than six reported specimens with cranial material (Bell 1997). The remains of the teleost consist of 5-10 vertebrae, many fin rays and fragments, and a few unidentifiable elements.

No investigations have been done in the District, although Bishop (1981) discussed several fossil localities in the general vicinity. These were outcrops of Pierre Shale that contain decapod crustaceans, specifically those typical of the *Dakoticancer* assemblage. These deposits also date to the Cretaceous Period.

Greis (1996) wrote a general summary of South Dakota geology, including the Cheyenne River basin. His summary of the basin parallels that of Bell (1995b) for the reservoir area in that Cretaceous sandstones, shale, limestones, clays, and chalk dominate both the Angostura area and the Cheyenne River basin. Table 3.39 summarizes Bell's review and assesses potential of each geological formation to contain paleontological resources.

Cretaceous sediments, which date to 145-66 million years ago, are the dominant fossil-bearing units. The Cretaceous is a relatively recent geologic period, erosion having had less effect than earlier periods (Thompson 1982). During the period, an inland sea extended from the Gulf of Mexico to the Arctic Ocean inundating most of the Great Plains, including South Dakota. Hence, fossil-bearing units around the reservoir date to the Cretaceous. These sediments contain remains of marine invertebrates, mollusks, marine reptiles, flying reptiles (pterosaurs), and rare dinosaurs. More recent fossil-bearing strata date to the Quaternary period, consisting primarily of gravel deposits with petrified wood and cycads (tree ferns).

The formations with the least potential for paleontological resources include the Unkpapa Sandstone, Lakota Formation, Fall River Formation, and Skull Creek Shale. No fossils have been identified in the Unkpapa; the Lakota and Fall River formations have yielded fossilized wood, clams, dinosaur bones, and primitive plants.

Formations with low-moderate potential include Mowry Shale and deposits from the Quaternary Period. The Mowry Shale contains invertebrate

Table 3.39: Geologic Formations and Potential for Paleontological Resources

Age	Formation (Oldest to Youngest)	Member	Fossil Potential
Cretaceous Period Deposits	Unkpapa Sandstone		Very low to none. No reported occurrences
	Lakota Formation	Chilson Minnewasta Limestone Fuson	Low. Reported occurrences Low. Reported occurrences Low. Reported occurrences
	Fall River Formation		Low. Some report occurrences
	Skull Creek Shale		Low. One reported occurrence
	Mowry Shale		Moderate. Reported occurrences
	Belle Fourche Shale		High. Reported occurrences
	Greenhorn Limestone		High. Reported occurrences
	Carlile Shale	Pool Creek Turner Sandy Sage Breaks	High. Reported occurrences High. Reported occurrences High. Reported occurrences
	Niobrara Formation		High. Reported occurrences
	Pierre Shale	Gammom Ferruginous Sharon Springs Mitten Black	Very high. Reported occurrences Very high. Reported occurrences Very high. Reported occurrences
	Chadron Formation		High. Reported occurrences
	Brule Formation		High. Reported occurrences
	Sharps Formation		High. Reported occurrences
Quaternary	Quaternary Deposits		Low to moderate. Reported occurrences

and vertebrate marine fossils, including teleost fish, sharks, sawfish, plesiousaurs, and ichthyosaurs. Quaternary deposits are unconsolidated sand, silt and gravel deposited on the flood plain of the Cheyenne River.

Fossils associated with these deposits are large vertebrates, petrified wood, and cycads.

Formations with the highest potential include Belle Fourche Shale, Greenhorn Limestone, Carlile Shale, Niobrara Formation, Pierre Shale, Chadron, Brule, and Sharps. Fossils in these formations are oyster, clam, shark, teleost fish, chimaerid fish, sawfish, turtle, plesiosaur, pterosaur, dinosaur, mosasaur, ammonite, birds and wood.

The town of Red Shirt.